JOURNAL OF
Environment
ISSN: 2615-9600
English Edition II-2025
INSTITUTE OF STRATEGY AND POLICY ON AGRICULTURE AND ENVIRONMENT - MAE

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PUBLICATION PERMIT
No 192/GP-BTTTT- Date: 31/05/2023

Photo on the cover page:
Son Ca island wind power system -
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Processed & printed by: Army Print No. 1
One Member Limited Liability Company, Ha Noi

English edition II/2025

Price: 30.000VND

CONTENTS

SUSTAINABLE TREATMENT OF SHRIMP AQUACULTURE WASTEWATER USING ATS–HRAP SYSTEM WITH CHLORELLA VULGARIS: A NATURE-BASED APPROACH FOR ENVIRONMENTAL PROTECTION

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Abstract
This study evaluates the effect of ATS substrate mesh size (0.2 mm, 0.6 mm, and 1 mm) and biomass retention time (7, 14, and 20 days) on nutrient removal efficiency and biomass development in an integrated High Rate Algal Pond (HRAP) system using Chlorella vulgaris for shrimp aquaculture wastewater treatment. A synthetic saline wastewater (7 ppt) simulating shrimp effluent was treated under controlled conditions. The results show that phosphate was removed most effectively, with average removal efficiencies reaching 86% under the 0.6 mm mesh and 7-day BRT. Total nitrogen removal peaked at 71.4% under the same condition. COD removal was modest, with a maximum of 22.1%, observed with the 1 mm mesh and 7-day BRT. Biomass accumulation was influenced by both substrate mesh size and retention time, with the highest MLVSS to MLSS ratios (above 0.75) found under mid-range mesh configurations. The findings highlight the role of substrate design and harvesting strategy in optimizing microalgae-based wastewater treatment systems and support the use of C. vulgaris as a feasible option for nutrient recovery and biomass production in saline aquaculture settings.
Keywords: *Algal Turf Scrubber; Biomass retention time; Chlorella vulgaris; Nutrient removal; Shrimp aquaculture wastewater.*
JEL Classifications: *Q53, Q55,Q57.*
Received: *24th April 2025****; Revised:*** *19th May 2025****; Accepted:*** *30th May 2025.*

1. INTRODUCTION

Intensive shrimp aquaculture is currently one of the fastest-growing sectors in global aquaculture, particularly in Asia. However, this rapid expansion poses serious environmental challenges. Shrimp farming generates large volumes of wastewater with high concentrations of organic matter, nitrogen, phosphorus, and persistent compounds that contribute to eutrophication, water quality degradation, and adverse impacts on coastal ecosystems if inadequately treated (Hang et al., 2024). It is estimated that only 20–25% of dietary nitrogen is assimilated by shrimp, with the remainder accumulating in the water column as ammonium, nitrate, and other nitrogenous compounds (Iber &Kasan, 2021). The direct discharge or insufficient treatment of shrimp effluent increases the risk of harmful algal blooms, hypoxia, biodiversity loss, and disease outbreaks (Dauda et al., 2019). Therefore, there is a critical need to develop effective and sustainable wastewater treatment systems that enable both pollution control and resource recovery.

In this context, microalgae-based treatment systems have emerged as promising solutions that simultaneously remove nutrients and produce biomass with economic value (Kusuma et al., 2024). Chlorella vulgaris, a fast-growing unicellular microalga, is known for its high nitrogen and phosphorus uptake capacity and its adaptability to saline environments typical of shrimp wastewater (Ahmad et al., 2020; Borowitzka, 2013). Under optimal cultivation conditions, C. vulgaris has been shown to remove over 90% of total nitrogen and phosphorus, while producing protein-rich biomass suitable for aquafeed or organic fertilizer applications (Safi et al., 2014).

The High Rate Algal Pond (HRAP) is one of the most widely adopted systems for microalgae-based wastewater treatment (Butterworth et al., 2024). HRAPs are shallow, mixed ponds designed to enhance light and CO_2 availability, thereby promoting algal growth and nutrient removal (Fallowfield et al., 2018). In contrast, Algal Turf Scrubber (ATS) systems involve wastewater flowing over inclined surfaces with attached substrates, where a mixed biofilm of algae and bacteria efficiently assimilates nutrients. ATS systems offer advantages such as high biomass retention, low washout rates, ease of harvesting, and minimal aeration requirements (Adey et al., 2011; Leong et al., 2021). Experimental studies have reported removal efficiencies of up to 99% for phosphorus and 84% for total nitrogen in aquaculture wastewater using ATS (Gan et al., 2022; Kishi et al., 2018).

However, most existing ATS studies focus on indigenous filamentous algae. The application of C. vulgaris in ATS systems remains limited due to its unicellular nature and low adhesion capacity, which increases its susceptibility to washout under continuous flow. Recent studies have indicated that C. vulgaris can produce extracellular polymeric substances (EPS) that enhance adhesion, especially when combined with appropriately sized mesh substrates (Shen et al., 2017; Wang et al., 2014). Additionally, design parameters such as ATS mesh size and biomass retention time (BRT) are critical determinants of treatment efficiency and biomass accumulation (Sutherland et al., 2020).

Based on these premises, this study aims to evaluate the effects of ATS mesh size (0.2 mm, 0.6 mm, and 1 mm) and biomass retention time (7, 14, and 20 days) on the removal efficiency of COD, total nitrogen, and phosphate, as well as on the biomass development of Chlorella vulgaris in an HRAP system integrated with ATS. The findings are expected to identify optimal operational conditions and contribute to the advancement of circular, scalable, and sustainable wastewater treatment technologies for intensive shrimp aquaculture.

2. MATERIALS AND METHODS

2.1. Materials and research subjects

The experimental system was established based on a High Rate Algal Pond (HRAP) model integrated with mesh substrates functioning as an Algal Turf Scrubber (ATS). Chlorella vulgaris was cultured under laboratory conditions at the Environmental and Sustainable Development Laboratory, Interdisciplinary Institute of Science, Nguyen Tat Thanh University. Prior to the treatment experiments, the algal culture was grown to a biomass concentration of approximately 106 cells/L.

Synthetic shrimp aquaculture wastewater was prepared to simulate typical effluent characteristics based on previously analyzed data. The formulated wastewater contained 120 mg/L of chemical oxygen demand (COD), 12.2 mg/L of total nitrogen (TN), 10.2 mg/L of ammonium ($N–NH_4^+$), 0.2 mg/L of nitrite ($N–NO_2$-), 1.6 mg/L of nitrate ($N–NO_3$-), and 1.0 mg/L of total phosphorus (TP), with salinity adjusted to approximately 7 parts per thousand (ppt).

2.2. Operating parameters of the model

The wastewater treatment system implemented in this study aimed to evaluate the growth performance of microalgae and the removal efficiency of pollutants through the integration of a High Rate Algal Pond (HRAP) and Algal Turf Scrubber (ATS) substrates. The HRAP unit was constructed with dimensions of 0.7 × 0.5 × 0.3 meters, resulting in a total volume of 96 liters and an effective operating volume of 90 liters. Within this configuration, the ATS substrates were suspended 5 centimeters above the water surface, serving as a biological attachment surface for Chlorella vulgaris. This design facilitated expanded light exposure zones and enhanced photosynthetic efficiency as well as nutrient uptake. Additionally, the ATS provided a supportive structure for microbial colonization, promoting nutrient assimilation and the biodegradation of organic and inorganic contaminants present in the wastewater.

The system operated under continuous low-speed mixing using a paddle wheel rotating at 20 revolutions per minute, ensuring stable flow, uniform light distribution, and optimal contact between microalgae and dissolved nutrients. An initial volume of 9 liters of microalgal culture was introduced, followed by the addition of synthetic wastewater to reach a total volume of 90 liters. Daily, 10 liters of synthetic shrimp wastewater were added and discharged at an equal volume, corresponding to a hydraulic retention time (HRT) of 9 days, while biomass retention time (BRT) was maintained at 10 days. The system was exposed to natural light with a 12:12 hour light–dark photoperiod, and ambient temperature ranged from 25 – 32°C. The pH was maintained at 7.0 ± 0.49 to support optimal physiological activity of both microalgae and associated microbial communities.

2.3. Experimental setup, sampling methods and frequency

2.3.1. Experimental setup

The experiment was designed to investigate the effects of key operational factors, specifically ATS mesh size and biomass retention time (BRT), on the treatment performance of the system. A series of continuous-flow trials were conducted under different combinations of these two variables. The ATS mesh sizes tested included 0.2 mm, 0.6 mm, and 1 mm, while the BRTs were set at 7, 14, and 20 days, respectively. Each treatment condition was operated independently under steady-state conditions, and system performance was monitored accordingly. The objective was to evaluate how variations in mesh size and biomass harvesting frequency influenced the removal efficiency of pollutants in shrimp aquaculture wastewater. The findings aimed to determine the most effective combination of ATS mesh size and retention time to optimize system performance.

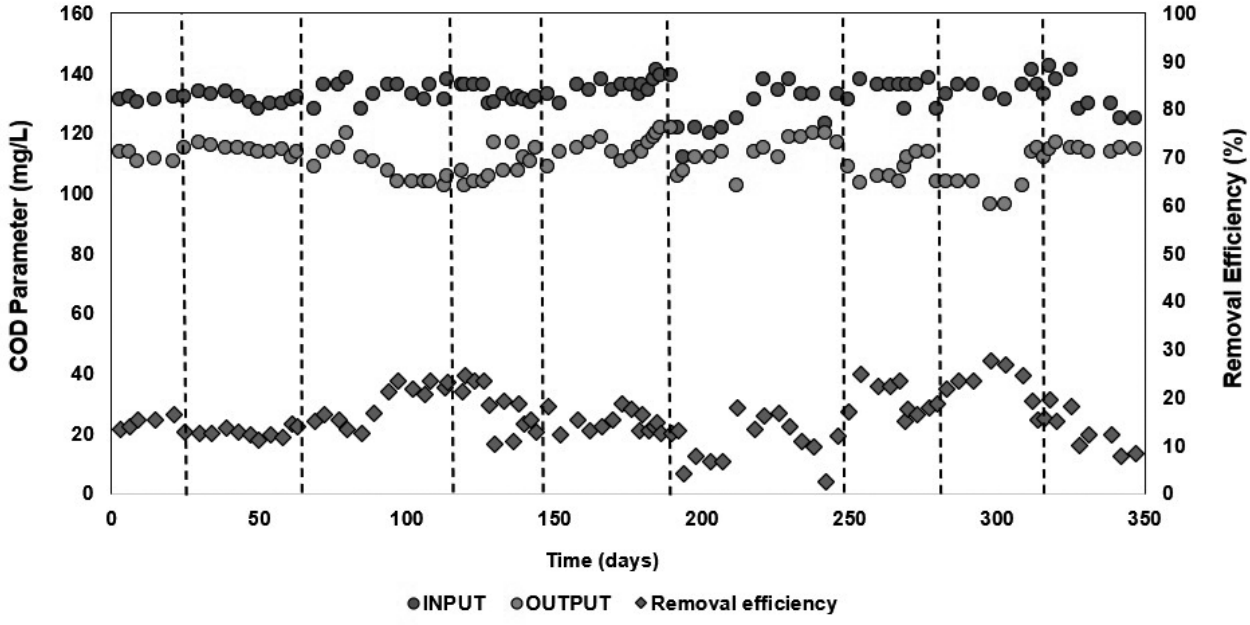

Figure 1. COD removal efficiency of the HRAP model integrated with ATS media under different treatments.

2.3.2. Sampling methods and frequency

To evaluate treatment performance, both influent and effluent samples were analyzed with a focus on specific environmental parameters. Chemical oxygen demand (COD) was measured following the Vietnamese standard TCVN 6186:1996, equivalent to ISO 8467:1993 (E), ensuring analytical accuracy and comparability. Total nitrogen (TN) was determined using the Standard Methods for the Examination of Water and Wastewater (SMEWW) 4500-N B and C. Orthophosphate ($P\text{-}PO_4^{3-}$), representing total phosphorus, was analyzed according to SMEWW 4500-P B and E (2012). For biomass characterization, mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were quantified based on SMEWW 2540 D (2012).

All samples were collected and analyzed three times per week across nine experimental treatments. The entire system was operated over a 30 to 40-day period to ensure the reliability and representativeness of the results.

3. RESULTS AND DISCUSSION

3.1. Evaluation of the pollutant removal efficiency of the HRAP Model Integrated with ATS Media

The microalga Chlorella vulgaris, when integrated into wastewater treatment systems, utilizes photosynthesis to degrade organic pollutants, thereby contributing to a reduction in chemical oxygen demand (COD) levels in the aquatic environment. This process parallels the assimilation of CO_2 during photosynthesis, wherein microalgae metabolize available organic substrates such as glucose, fructose, amino acids, and fatty acids. The consumption of these compounds by C. vulgaris leads to a concurrent decrease in COD concentrations, thus enhancing the treatment performance of photobioreactor-based systems such as High-Rate Algal Ponds (HRAPs).

As illustrated in Figure 1, the influent COD concentration remained relatively stable, with an average value of 132.7 mg/L, peaking at 142.4 mg/L and dropping to a minimum of 112 mg/L. These values indicate a controlled and consistent synthetic wastewater composition during the experimental period. In contrast, effluent COD values exhibited greater variability, with an average of 111.5 mg/L, ranging from a low of 96 mg/L to a high of 121.6 mg/L. This fluctuation reflects the influence of operational conditions on treatment efficiency.

The system's average COD removal efficiency was approximately 15.85%, with a maximum observed removal of 29.41% and a minimum of only 4.29%. Although the overall COD removal performance was modest, the experimental conditions had a marked impact on treatment outcomes. In treatments employing finer ATS mesh sizes (0.2 mm) and shorter biomass retention times (BRT) of 7 days, COD removal efficiency ranged between 13% and 16%, likely due to limited algal contact time and retention. However, increasing the BRT to 14 or 20 days particularly in the treatment condition with a 0.6 mm mesh size and 20-day BRT resulted in significantly improved removal rates, with values frequently ranging from 22% to 27%. The

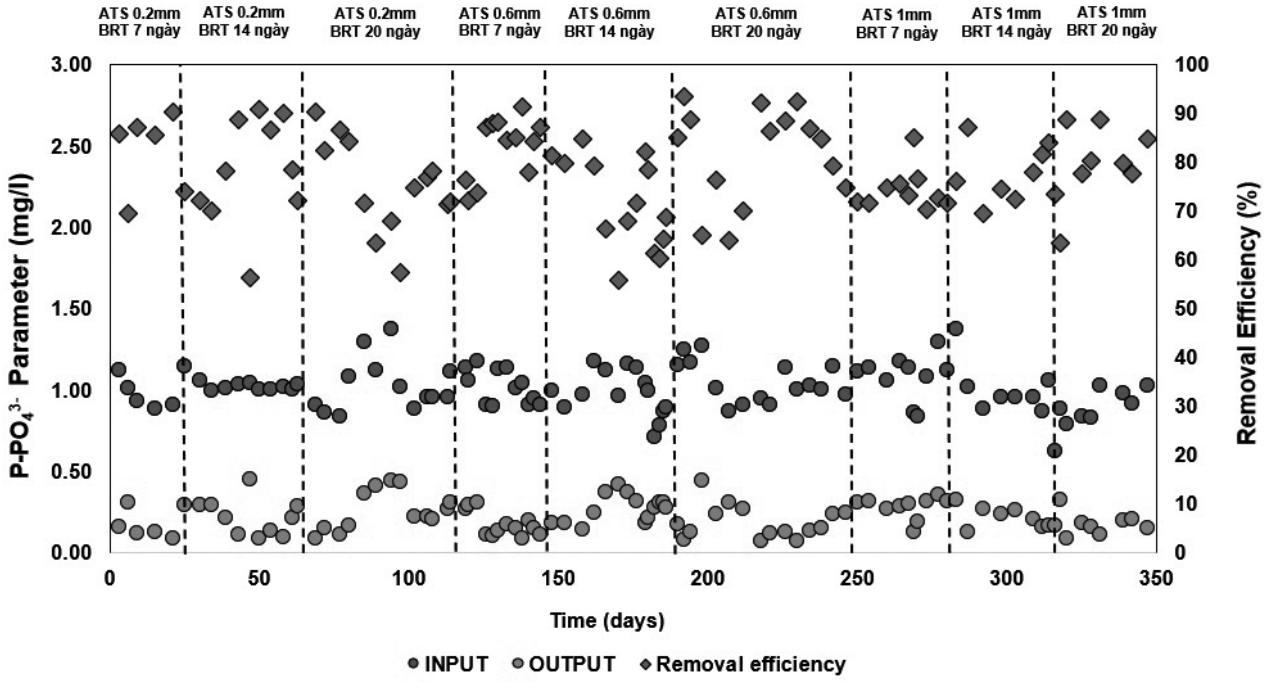

Figure 2. P-PO_4^{3-} removal efficiency of the HRAP model integrated with ATS media under different treatments.

highest efficiency (29.41%) was recorded on days 298 and 303 under the condition with a 1 mm mesh size and 20-day BRT.

These findings suggest that prolonged biomass retention combined with larger ATS mesh sizes favors algal growth, enhances organic matter uptake, and extends algal residence time within the system, thereby improving overall treatment performance. Such biofilms promote a balanced bacterial community and facilitate synergistic interactions, reducing biomass washout and promoting microbial oxidation processes (Craggs & Technology, 2001; Villar-Navarro et al., 2018). Moreover, shorter retention times involve more frequent harvesting, which helps remove older algal and microbial biomass, thereby maintaining a younger and metabolically active biomass population that contributes to consistent COD removal efficiency (Magalhães et al., 2024).

After removing outlier values, phosphate data analysis revealed that the HRAP system integrated with an Algal Turf Scrubber (ATS) achieved consistently high and stable removal efficiencies across most experimental conditions, as illustrated in Figure 2. The application of microalgae for nutrient removal from wastewater while simultaneously recovering biomass has been widely documented in the literature (Wang et al., 2012). Notably, certain microalgal strains are capable of uptaking phosphorus in quantities exceeding their immediate growth requirements, particularly under suboptimal nutrient conditions. Recent findings indicate that phosphorus assimilated by microalgae is not solely allocated to biosynthesis processes but can also be stored intracellularly in the form of polyphosphate (Poly-P), a distinctive cellular storage compound (Harold, 1966).

The influent phosphate (PO_4^{3-}) concentrations ranged from 0.72 to 1.38 mg/L, with an average value of approximately 1.02 mg/L. In contrast, the effluent concentrations ranged from 0.07 to 0.46 mg/L, with an average reduced to 0.22 mg/L. This substantial difference between influent and effluent concentrations indicates the system's high phosphorus removal capacity under various operational scenarios. Phosphorus removal efficiencies, after excluding outlier data, ranged from 55.77% to 93.60%, with an average efficiency of 78.31%, which surpasses the 71% reported by Picot et al. (1991). These results demonstrate excellent treatment performance, particularly considering the system utilizes a consortium of Chlorella vulgaris and heterotrophic bacteria for wastewater remediation.

When analyzed by experimental phase, the configurations employing ATS mesh sizes of 0.2 mm and 0.6 mm combined with biomass retention times (BRT) of 7 to 14 days exhibited high and stable phosphorus removal efficiencies, with several

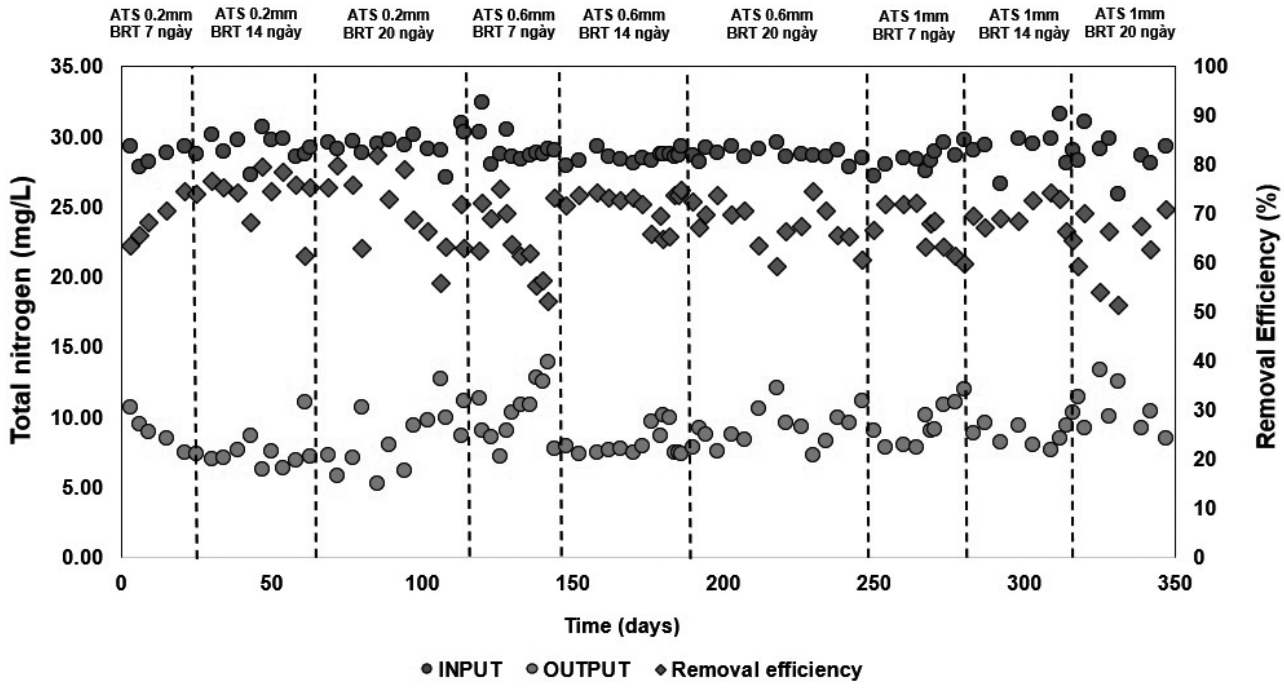

Figure 3. Total nitrogen removal efficiency of the HRAP model integrated with ATS media.

measurements exceeding 85%. This suggests that smaller mesh sizes provide enhanced surface area for microalgal attachment and optimal light exposure, which facilitate nutrient assimilation. Conversely, treatments using 1 mm ATS mesh and shorter BRTs showed slightly lower removal efficiencies, ranging between 65% and 75%. This reduction may be attributed to the decreased effective contact area due to the larger mesh size, which in turn reduces algal attachment density and phosphorus uptake. Moreover, shorter BRTs may not allow sufficient time for biomass development and phosphorus accumulation, thereby limiting overall treatment efficiency.

Chlorella vulgaris is a photosynthetic microalga capable of nitrogen uptake from wastewater through assimilation during photosynthesis. In addition to microalgae, bacteria play a crucial role in nitrogen removal, particularly through the transformation of organic nitrogen compounds into oxidized forms such as nitrate (NO_3^-) and nitrite (NO_2^-) via nitrification processes. While bacteria can also assimilate total nitrogen, they predominantly utilize ammonia as their primary nitrogen source for biomass synthesis, including the production of proteins and cellular components. The integration of Chlorella vulgaris with nitrifying bacteria in wastewater treatment systems enhances nitrogen removal efficiency by coupling algal assimilation with microbial nitrification and denitrification.

Total nitrogen removal efficiency is illustrated in Figure 3. The average removal efficiency was 68.55%, with a maximum value of 82.05% and a minimum of 51.51%. Compared to other treatment indicators, this is a relatively high performance, especially considering that the system operated without any chemical coagulants or external support technologies, relying solely on microalgae and the ATS structure. The nitrogen removal mechanism is primarily driven by the assimilative capacity of Chlorella vulgaris and its symbiotic interactions with associated bacteria. Under optimal light conditions and biomass retention times (BRT), the microalgae absorb ammonium and nitrate for growth, while simultaneously supplying oxygen to support bacterial nitrification and subsequent denitrification within the system.

Performance analysis across different experimental treatments indicated that configurations using smaller ATS mesh sizes (0.2 mm and 0.6 mm) combined with longer BRTs (14 to 20 days) achieved higher nitrogen removal efficiencies, with many measurements ranging from 70% to over 75%. In contrast, treatments utilizing 1 mm mesh and short BRTs (7 days) tended to exhibit slightly reduced removal efficiency, with values falling below 65% in some instances. This reduction may be attributed to a decrease in effective surface area and algal biomass density due to the larger mesh size,

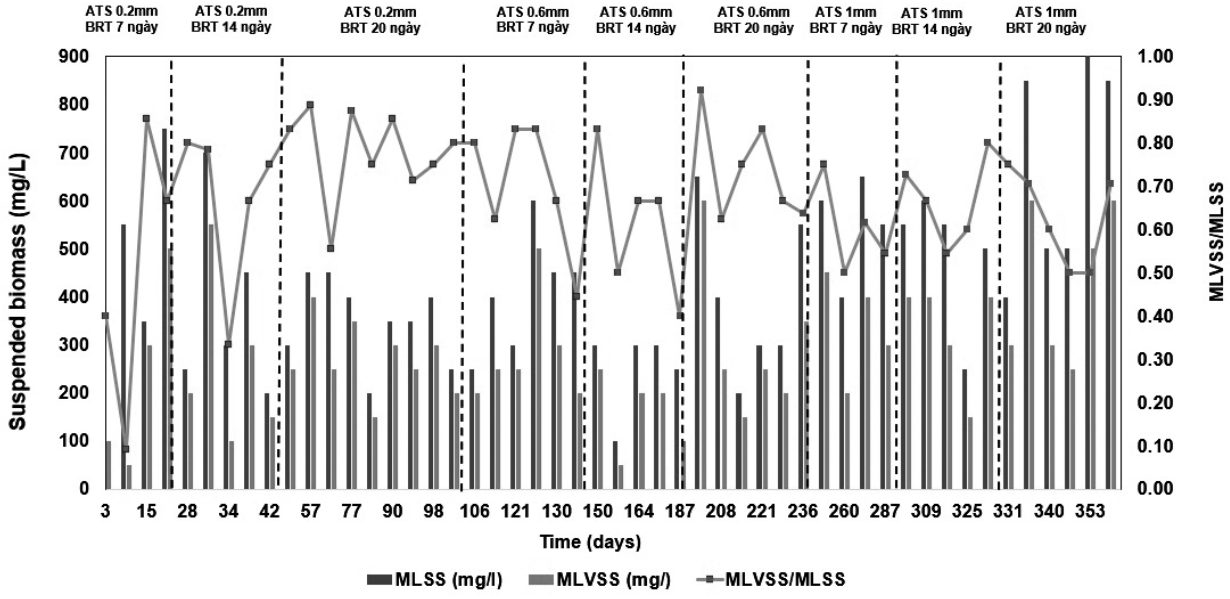

Figure 4. MLSS and MLVSS biomass in the HRAP model integrated with ATS media

along with insufficient biomass accumulation under shorter retention periods, which collectively limited the system's nitrogen removal capacity.

3.2. Evaluation of biomass development in the system

MLSS (Mixed Liquor Suspended Solids) and MLVSS (Mixed Liquor Volatile Suspended Solids) are critical indicators used to evaluate biomass transformation efficiency in wastewater treatment systems employing both bacteria and microalgae. MLSS represents the total concentration of suspended solids in the mixed liquor, comprising bacterial and algal biomass along with organic and inorganic particulates present in the treatment process. This parameter reflects the density of microbial and algal populations within the system. Monitoring MLSS provides insight into the pollutant load and treatment performance, enabling appropriate adjustments in nutrient supply and hydraulic loading. MLVSS, a subset of MLSS, represents the volatile fraction primarily attributed to active biomass. Collectively, MLSS and MLVSS monitoring serves as a valuable tool for assessing system performance, optimizing operational conditions, and maintaining biological balance for effective wastewater remediation.

As illustrated in Figure 4, the biomass accumulation within the treatment system was generally favorable, with total MLSS reaching approximately 376g and average MLVSS values around 258g. This indicates robust growth of both microalgae and microbial communities. Notably, during the phase utilizing an ATS mesh size of 0.6 mm, MLSS and MLVSS values exhibited significant variation, with MLSS peaking at approximately 750g and MLVSS reaching 500g. The MLVSS/MLSS ratio ranged from 0.6 to 0.8, suggesting a high proportion of active biomass and well-maintained algal and microbial growth dynamics. In contrast, during the phase with a 1 mm mesh size, biomass formation remained stable, yet the larger pore size appeared to limit algal and microbial development. Consequently, total biomass values ranged from 200 to 450g, and the MLVSS/MLSS ratio decreased slightly to 0.45-0.8. These observations indicate that both mesh size and biomass retention time (BRT) on the ATS influence biomass accumulation. Specifically, smaller mesh sizes provide more favorable conditions for organic biomass growth due to enhanced surface area for attachment and optimal light exposure.

4. CONCLUSION

The results demonstrate that ATS mesh size and biomass retention time are key factors influencing the pollutant removal efficiency of the HRAP–ATS system. The use of Chlorella vulgaris enabled stable biofilm formation and effective treatment under simulated saline wastewater conditions (7 ppt). The highest COD removal (22.1%) was achieved using a 1 mm mesh with a 7-day retention time, while phosphate and total nitrogen removal reached 86.1% and 71.4%, respectively, under a 0.6 mm mesh and 7-day retention. These findings confirm that optimizing substrate configuration and harvesting intervals enhances both nutrient removal and biomass productivity. This study provides a practical foundation for designing sustainable and biologically integrated wastewater

treatment systems for application in aquaculture and similar saline environments.

Acknowledgments: *This research was supported by Nguyen Tat Thanh University, Ho Chi Minh City.*
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OPTIMIZATION OF ENVIRONMENTAL FACTORS FOR ENHANCING GROWTH AND POLLUTANT REMOVAL EFFICIENCY OF THE CYANOBACTERIUM SYNECHOCYSTIS SALINA M8 IN DOMESTIC WASTEWATER

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Abstract

Microalgae biotechnology has attracted widespread attention due to its potential for wastewater treatment and the recovery of biomass with economic value. This study focuses on evaluating the effects of several environmental factors on the growth and domestic wastewater treatment efficiency of the photoautotrophic cyanobacterium Synechocystis salina M8, which was isolated from agricultural water sources in Vietnam. Laboratory-scale experiments were conducted using two types of culture media (BG-11 and domestic wastewater), under different pH levels and C:N:P nutrient ratios, to determine the optimal conditions for the growth of S. salina M8 and its pollutant removal performance. The study employed standard methods for sampling and wastewater analysis in the laboratory, along with techniques for assessing the growth of S. salina M8. The results showed that S. salina M8 exhibited good growth in both culture media, particularly in domestic wastewater under mixotrophic conditions with aeration. Biomass productivity reached 1.34 g/L in non-sterilized BG-11 medium and peaked at 1.64 g/L in domestic wastewater. After 8 days of cultivation under optimal conditions - including an inoculum ratio of 20–25% (v/v), pH 7, temperature of 27°C, aeration at 0.1 vvm, light intensity of 4500 Lux, and a C:N:P ratio of 100:10:1 - the treatment efficiency reached approximately 75% for COD, and over 80% for $N–NH_4^+$, total nitrogen (T-N), $P–PO_4^{3-}$, and total phosphorus (T-P). The treated water met the standards set by QCVN 14:2008/BTNMT, Column B. These findings confirm the potential of S. salina M8 for application in sustainable and environmentally friendly domestic wastewater treatment, while simultaneously generating biomass for the production of valuable products. This contributes to the advancement of green technologies and supports the development of a circular economy model.

Keywords: *Domestic wastewater, Mixotrophy, Biomass, S. salina M8.*

JEL Classifications: *Q25, Q53, Q55.*

Received: *4th February 2025;* ***Revised:*** *3rd March 2025;* ***Accepted:*** *17th March 2025.*

1. INTRODUCTION

Currently, water pollution has become a major global concern, particularly in large urban areas such as Hanoi. The rapid pace of urbanization, coupled with population growth, has led to the generation of a substantial volume of domestic wastewater each day. In Hanoi, each resident discharges approximately 100 - 150 liters of wastewater per day, bringing the total volume of domestic wastewater in the city to nearly 1 million cubic meters per day (Anh, T. T. D., 2022). However, according to the Ministry of Natural Resources and Environment (2023), only about 18% of urban wastewater is currently collected and treated at centralized treatment plants. The remaining portion is often discharged directly into the environment without treatment, resulting in serious pollution, eutrophication, and adverse impacts on aquatic ecosystems and public health. Domestic wastewater contains high levels of organic matter, nitrogen and phosphorus compounds, pathogenic microorganisms, and toxic micro-pollutants. Current treatment technologies mainly rely on aerobic, anaerobic, or anoxic biological processes. However, these conventional methods generate large amounts of sludge that require further treatment and are often not environmentally friendly.

In response to the current situation, the development of efficient, environmentally friendly, and cost-effective wastewater treatment technologies with potential for resource recovery has become an urgent necessity. Among the promising approaches, the application of photoautotrophic microorganisms - particularly microalgae and cyanobacteria has attracted significant attention. These microorganisms are capable of assimilating pollutants such as chemical oxygen demand (COD), nitrogen, and phosphorus through photosynthesis. Moreover, the biomass generated during the treatment process can

be reused for the production of fertilizers, animal feed, biofuels, or other high-value compounds. For instance, Chlorella variabilis TH03 has demonstrated the ability to remove up to 99,9% of phosphorus and 96,1% of nitrogen within just 14 - 17 days (Dang Thuan Tran et al., 2021). In another study, Synechocystis sp. cultured in wastewater enriched with NH_4^+ and PO_4^{3-} achieved nutrient removal efficiencies of 96,99% for phosphate, 80,10% for nitrate, 67,90% for nitrite, and 98,07% for ammonium (N. Krasaesueb, A. et al., 2019). Recent research has also shown that microalgae can be cultivated not only under photoautotrophic conditions but also under heterotrophic and photo-mixotrophic regimes. Under heterotrophic conditions, microalgae grow using organic carbon sources without the need for light, enabling effective removal of organic matter, nitrogen, and phosphorus from wastewater compared to conventional autotrophic cultivation (Santos, C. A bet al., 2020). On the other hand, photo-mixotrophic cultivation which has recently received increasing research interest allows microalgae to simultaneously utilize both organic and inorganic carbon sources, along with nitrogen and phosphorus nutrients in wastewater, thereby improving the efficiency of pollutant removal (Voulvoulis, N et al., 2017).

Although this has been documented in several microalgal species such as Arthrospira platensis (M. I. B. Pereira et al., 2019), the application of the photo-mixotrophic cultivation mode for the cyanobacterium Synechocystis salina M8 in domestic wastewater treatment remains limited in Vietnam. This strain exhibits the ability to grow in both freshwater and saline environments and contains phycocyanin and chlorophyll – a pigments that enhance light absorption efficiency. S. salina M8 has been shown to remove up to 96% of phosphorus and 66% of nitrogen after only a few days of cultivation (Trentin et al., 2019), while also accumulating proteins, polysaccharides, and polyhydroxybutyrate (PHB) - a key raw material for the bioplastics industry. In addition, S. salina M8 demonstrates robust growth in organic-rich environments and can accumulate a substantial amount of high-value compounds such as proteins, polysaccharides, and polyhydroxybutyrate (PHB) – a type of biodegradable biopolymer. The objective of this study is to investigate the growth performance of S. salina M8 in both the standard BG-11 medium and in sterilized and non-sterilized domestic wastewater under two mixing conditions: magnetic stirring and aeration. The experiments also explore the effects of different pH levels and C:N:P nutrient ratios. Moreover, the study evaluates the strain's wastewater treatment capability and biomass accumulation potential, aiming to develop practical applications in eco-friendly, cost-effective domestic wastewater treatment systems aligned with the principles of green technology and the circular economy.

2. MATERIALS AND METHODS

2.1. Materials and experimental equipment

2.1.1. Source of algal inoculum

The cyanobacterial strain S. salina M8 was obtained from the culture collection maintained and cultivated at the Biochemical Technology Laboratory, Institute of Chemistry, Vietnam Academy of Science and Technology, located at 18 Hoang Quoc Viet, Hanoi.

Prior to experiments, S. salina M8 was pre-cultivated in BG-11 medium (Table 1). Cultivation was carried out in 250 mL Erlenmeyer flasks with a working volume of 100 mL. The cultivation conditions were maintained at

Table 1. Composition of 1 liter of BG-11 medium

No.	Chemical Name	Formula	Concentration (g/L)
1	Sodium nitrate	$NaNO_3$	1,5
2	Dipotassium phosphate	K_2HPO_4	0,04
3	Magnesium sulfate heptahydrate	$MgSO_4 \cdot 7H_2O$	0,075
4	Calcium chloride dihydrate	$CaCl_2 \cdot 2H_2O$	0,036
5	Citric acid	$C_6H_8O_7$	0,006
6	Ferric ammonium citrate	$(NH_4)_5[Fe(C_6H_4O_7)_2]$	0,006
7	Disodium ethylene diaminete traacetate dihydrate	$Na_2EDTA \cdot 2H_2O$	0,001
8	Sodium carbonate	Na_2CO_3	0,02
9	Trace metal mix (A5): H_3BO_3: 2,86g/L; $MnCl_2.4H_2O$: 1,81 g/L; $ZnSO_4.7H_2O$: 0,222g/L; $Na_2MO_4.2H_2O$: 0,39g/L; $CuSO_4.5H_2O$: 0,079g/L; $Co(NO_3)_2.6H_2O$: 0,049 g/L.		1 mL/L

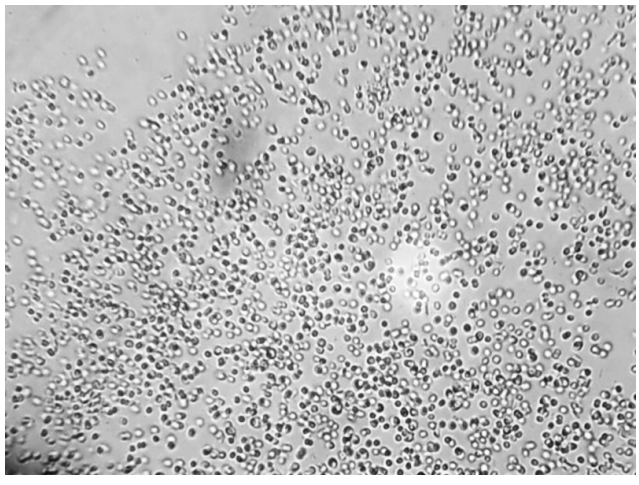

Figure 1. Morphology of cyanobacterium S. salina M8

Figure 2. Inoculum cultivation of S. salina M8 in a 250 mL Erlenmeyer flask

a temperature of approximately 25–27°C under illumination from two fluorescent lamps providing a light intensity of 4.500 Lux with a 24-hour continuous light cycle. Aeration was supplied at 0.1 vvm and magnetic stirring was set at 150 rpm using a 1.000 mL Duran flask containing 500 mL of BG-11 medium.

2.1.2. Domestic wastewater

Domestic wastewater samples were collected from two wastewater discharge drains in the residential area of Nguyen Chanh Street, Cau Giay District, Hanoi. The sampling locations were at the wastewater drainage points in alley 48 Nguyen Chanh, coordinates: X_1 = 2,325,145; Y_1 = 572,270, and alley 39 Tu Mo Street, coordinates: X_2 = 2,345,350; Y_2 = 580,543.

Table 2. Experimental instruments and equipment

No	Equipment	Model/ Specification	Manufacturer
1	Analytical balance	JF2204	Labex – UK
2	Centrifuge	Z206A	Hermle – Germany
3	Ultrasonic cleaner	Ultrasonic Cleaner	UK
4	Autoclave	LS-75LJ	Nanbei – China
5	Oven and incubator	—	Heraeus – Germany
6	Microscope	Optical microscope	OLYMPUS – Japan
7	UV-Vis spectrophotometer	U-2900/2910	Shimadzu – Japan
8	LED lighting	—	Rang Dong – Vietnam
9	Air pump	HP-400	Atman – China
10	Air flow regulator	—	Vietnam
11	Air filter head	0.22 μm	China
12	Silicone tubing	—	China
13	Glass culture flasks	1L, 2L, 3.5L, 5L	SIMAX – Germany
14	Measuring cylinders	25, 50, 100, 1000 mL	Germany
15	Volumetric flasks	1000 mL	Germany
16	Erlenmeyer flasks	50 mL, 250 mL	Germany

2.1.3. Laboratory Equipment

2.2. Experimental design

2.2.1. Investigation of the effects of artificial BG-11 medium and domestic wastewater on the growth of S. salina M8

The S. salina M8 cyanobacterial strain was maintained in 1.000 mL Duran flasks as described in Section 2,1 for 6–8 days to reach a cell density above 2,5 × 10^5 cells/mL (equivalent to OD_{750} = 2,5 Abs or 1,0 g/L). Subsequently, the S. salina M8 inoculum was transferred into 1.000 mL Duran flasks containing sterilized or non-sterilized BG-11 medium or domestic wastewater at an inoculation ratio of 20% (v/v). Cultivation was carried out under aeration conditions (0,1 vvm) and magnetic stirring (150 rpm), with the initial pH adjusted to 7, under a light intensity of 4.500 Lux for 8 days. Each experiment was conducted in triplicate. The bioreactors were equipped with three stainless steel (304 grade) ports (Φ6 mm) for aeration, sampling, and gas exhaust. The stainless steel aeration port was connected via silicone tubing to a flow meter linked to a Fujimac aeration pump.

2.2.2. Investigation of the effect of pH on the growth of S. salina M8 and the efficiency of domestic wastewater treatment.

The experiment was conducted in 1-liter Duran flasks at pH values of 5, 6, 7, 8 and 9, with pH adjusted

Figure 3. Experiment on culturing S. salina M8 in domestic wastewater

using NaOH 5M/H_2SO_4 5M. The initial inoculation ratio of S. salina M8 was set at 20% (v/v). Experimental conditions were maintained as follows: temperature of 25 - 27°C, aeration at 0,1 vvm, light intensity of 4.500 Lux under continuous illumination (24-hour light cycle), and aeration at 0,1 vvm. Each experiment was performed in triplicate. The growth rate and domestic wastewater treatment efficiency of S. salina M8 were monitored over 8 days. The water quality parameters analyzed after treatment included ammonium nitrogen (N–NH_4^+), total nitrogen (T-N), total phosphorus (T-P), phosphate (PO_4^{3-}) and chemical oxygen demand (COD).

2.2.3. Investigation of the effect of C:N:P ratios on the growth capability of S. salina M8 and its efficiency in treating domestic wastewater.

The experiment was conducted in 1-liter Duran flasks with C:N:P ratios of (100:10:1), (100:5:1), (100:10:0.5), and (100:15:1). Nutrient composition was adjusted by supplementing carbon sources (CO_2 or acetate), nitrogen ($NaNO_3$), and phosphorus (K_2HPO_4). The experimental conditions were as follows: temperature 25 - 27°C, aeration at 0,1 vvm, light intensity of 4500 Lux, continuous illumination (24 hours light), an initial inoculum ratio of S. salina M8 at 20% (v/v), and pH adjusted to 7. Each experiment was performed in triplicate. The growth rate and domestic wastewater treatment efficiency of S. salina M8 were monitored over 8 days. Water quality parameters analyzed in the treated wastewater included NH_4-N, total nitrogen (T-N), total phosphorus (T-P), PO_4^{3-} and COD.

2.3. Research methods

2.3.1. Sampling and laboratory analysis methods for wastewater

Wastewater samples were collected according to the Vietnamese standard TCVN 5999:1995 (ISO 5667/10:1992) on water quality – sampling – guidance on sampling of wastewater. Sample preservation was conducted following the national standard TCVN 6663-3:2016 (ISO 5667-3:2012) on water quality – sampling – Part 3: Preservation and handling of water samples. Wastewater was collected in 5–10 L plastic containers and transported to the Biochemical Technology Laboratory, Institute of Chemistry, Vietnam Academy of Science and Technology. Prior to experimentation, wastewater was pretreated by filtration through filter paper with pore sizes of 3–7 μm for 30 minutes to remove debris and suspended solids. Initial parameters including COD, NH_4^+, NO_3^-, PO_4^{3-}, total nitrogen (TN), and total phosphorus (TP) were measured immediately upon arrival at the laboratory. Final parameters were analyzed after 8 days of cultivation. Analytical methods used were as follows: NH_4 according to TCVN 6179-1:1996; NO_3 according to TCVN 6180:1996 and ISO 7890-3:1998 (E); phosphorus analysis according to TCVN 6202:2008 using the ammonium molybdate spectrophotometric method; COD according to TCVN 6491:1996. The initial quality parameters of the pretreated influent wastewater were: pH = 7,2 ± 0,2; COD = 325,6 ± 0,3 mg/L; NO_3^- = 3,2 ± 0,1 mg/L; NH_4^+ = 32,12 ± 0,42 mg/L; TN = 36,12 ± 0,52 mg/L; P-PO_4^{3-} = 4,24 ± 0,15 mg/L; TP = 5,2 ± 0,2 mg/L; total suspended solids (TSS) = 1,21 ± 0,2 mg/L. The initial C:N:P ratio of the domestic wastewater was 63:7:1. The experiments were arranged using a completely randomized design with independent variables including pH and C:N:P ratio. The dependent variable was optical density (OD_{750}). Each experiment was repeated three times to ensure statistical reliability. Results are presented as mean values ± standard deviation. Raw data were processed using Microsoft Excel 2016. The removal efficiencies of COD, NH_4^+-N, total nitrogen (T-N), PO_4^{3-}P, and total phosphorus (T-P) were calculated using the formula:

$$H_i = (1 - \frac{C_i}{C_{0i}}) \times 100$$

Hi - the removal efficiency (%); C0i - the concentration of the parameter in the influent wastewater (mg/L); Ci - the concentration of the parameter in the treated wastewater (mg/L).

2.3.2. Method for evaluating the growth of S. salina M8

The growth of the cyanobacterium was monitored daily by measuring the optical density at a wavelength of 750 nm (OD_{750})

using a UV-Vis spectrophotometer (Shimadzu, Japan). Dry cell weight (DCW) was determined by collecting 10 mL of the cyanobacterial culture, filtering it through a 0,45 μm membrane, and drying it at 105°C for 24 hours to obtain the dried biomass. Biomass concentration (g/L) was calculated based on the dry weight of biomass obtained per liter of culture.The specific growth rate (μ, day^{1}) of the cyanobacterial strain was determined using the following equation (1):

$$\mu = \frac{\ln \frac{X_2}{X_1}}{t_2 - t_1} \quad (1)$$

X1 and X2 are the biomass concentrations (g/L) of Synechocystis salina M8 measured at cultivation times t1 and t2 (days), respectively.

3. RESULTS AND DISCUSSION

3.1. Analysis of domestic wastewater samples in the study area

The analysis results in Table 3 show that the filtered domestic wastewater, prior to treatment with Synechocystis salina M8, exhibited a neutral pH environment. The chemical oxygen demand (COD) concentration ranged around 325,6 ± 0,3 mg/L. The wastewater was rich in nitrogen, with a high concentration of ammonium nitrogen (NH_4^+-N) at approximately 32,12 ± 0,42 mg/L, while nitrate nitrogen (NO_3^--N) was present at a lower level of 3,2 ± 0,1 mg/L. Phosphate (PO_4^{3-}), the predominant form of phosphorus found in domestic wastewater, was recorded at a concentration of 4,24 ± 0,15 mg/L. The total nitrogen (T-N) and total phosphorus (T-P) contents were found to be 36,12 ± 0,52 mg/L and 5,2 ± 0,2 mg/L, respectively. Total suspended solids (TSS) after filtration were approximately 1,21 ± 0,2 mg/L, a level that does not hinder light penetration into the water. The pH of the domestic wastewater collected from the sewer was considered suitable for the cultivation of S. salina M8, aligning well with the optimal conditions of the standard BG-11 medium.

The research results indicate that the domestic wastewater used in this experiment contains essential nutrients such as carbon, nitrogen, and phosphorus compounds necessary for the growth of microalgae. These findings are consistent with those reported by Dang Thuan Tran and colleagues in 2021 (D.T. Tran et al., 2021). Therefore, in subsequent experiments, domestic wastewater was used as the cultivation medium for Synechocystis salina M8.

Table 3. Characteristics of domestic wastewater (after pre-treatment, before inoculation) (n=3)

No.	Parameter	Unit	Concentration	QCVN 14:2008/ BTNMT Column B
1	pH	-	7,3 ± 0,2	**5-9**
2	Temperatur	°C	25,67± 0,21	-
3	TSS	mg/L	1,4± 0,2	**100**
4	N-NO_3-	mg/L	3,2 ± 0,1	**50**
5	N-NH_4^+	mg/L	32,12 ± 0,42	**10**
6	Total Nitrogen	mg/L	36,12± 0,52	-
7	P-PO_4^{3-}	mg/L	4,24 ± 0,15	**10**
8	Total Phosphorus	mg/L	5,2 ± 0,2	-
9	COD	mg/L	325,6 ± 0,3	-

3.2. Effect of culture medium and mixing regime on the growth of S. salina M8

The culture medium is a key factor that directly affects the growth performance of S. salina M8. Figure 2 presents the specific growth rate and biomass productivity of S. salina M8 when cultured in standard BG-11 medium and in domestic wastewater, under both sterilized and non-sterilized conditions, using two mixing regimes: magnetic stirring and aeration. The results demonstrated that the type of culture medium whether standard BG-11 or domestic wastewater, sterilized or not - did not exhibit significant effects on the growth of S. salina M8. In contrast, the mixing regime had a substantial impact on both growth rate and biomass productivity. Specifically, under magnetic stirring at 150 rpm in sterilized BG-11, S. salina M8 reached a specific growth rate of (0,16 ± 0,01) day^{1} and biomass productivity of (0,72 ± 0,01) g/L (Figure 2A). In non-sterilized BG-11, the specific growth rate and biomass productivity increased slightly to (0,21 ± 0,01) day $^{-1}$ and (0,78 ± 0,02) g/L, respectively (Figure 2B). When aeration was applied at a rate of 0.1 vvm, the specific growth rate and biomass productivity of S. salina M8 increased to (0,46 ± 0,02) day $^{-1}$ and (1,12 ± 0,015) g/L in sterilized BG-11 medium (Figure 2A), and to (0,42 ± 0,02) day $^{-1}$ and (1,34 ± 0,01) g/L in non-sterilized BG-11 medium (Figure 2B). Similarly, under magnetic stirring conditions, S. salina M8 cultured in sterilized and non-sterilized domestic wastewater achieved specific growth rates and biomass productivities of (0,28 ± 0,01) day $^{-1}$ and (0,85 ± 0,02) g/L (Figure 2C), and (0,42 ± 0,03) day $^{-1}$ and (0,92 ± 0,02) g/L (Figure 2D), respectively. Under aeration, S. salina M8 showed even higher performance in domestic wastewater: in the sterilized condition, the specific growth rate and biomass productivity reached (0,54 ±

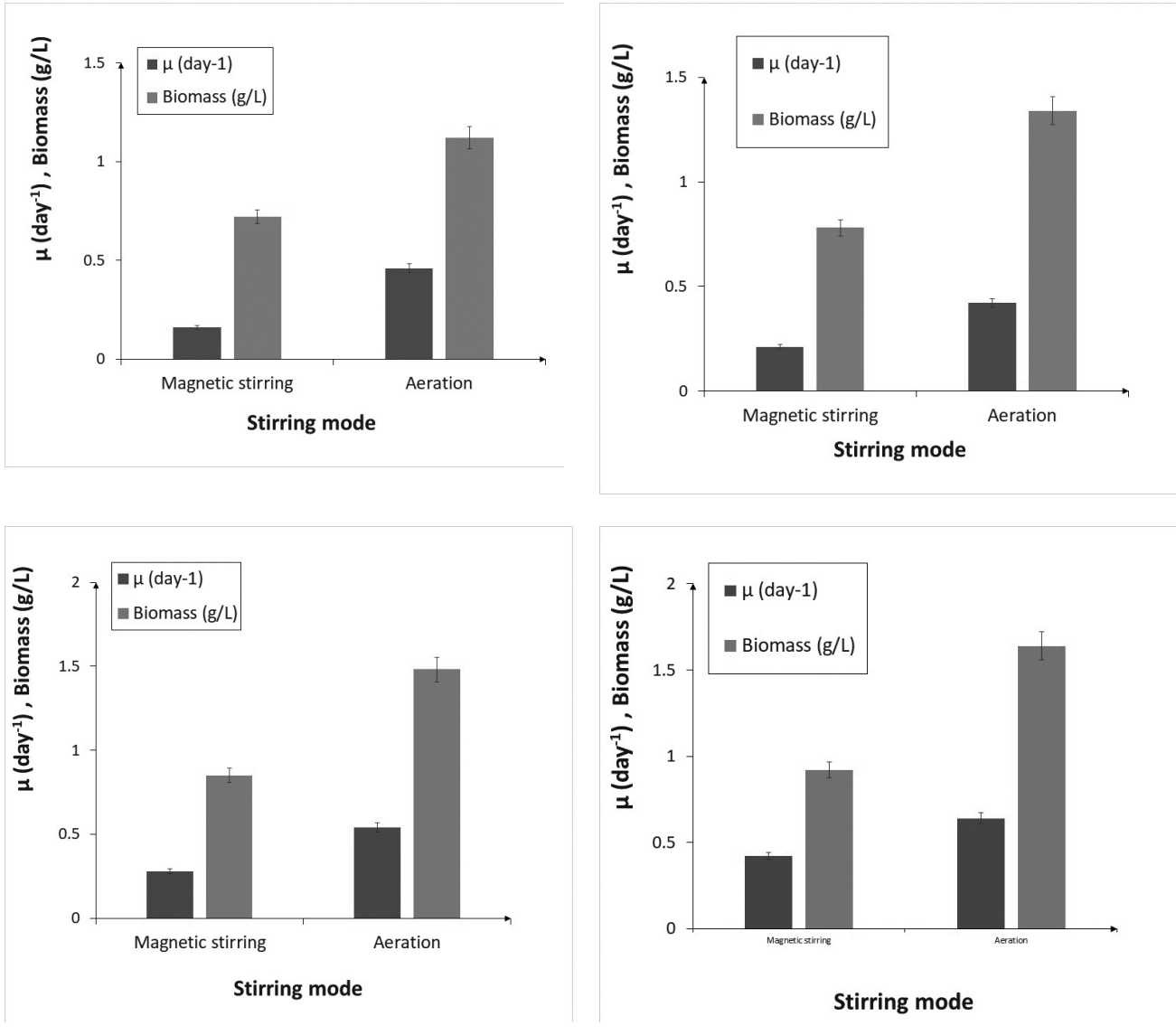

Figure 4. Specific Growth Rate and Biomass of S. salina M8 in Sterilized BG-11 (A), Non-sterilized BG-11 (B), Sterilized Wastewater (C), and Raw Wastewater (D) under Two Mixing Regimes: Magnetic Stirring and Aeration. Data were collected on the 8th day of cultivation under light intensity of 4.500 Lux and temperature of 27°C

0,015) day^{-1} and (1,48 ± 0,02) g/L (Figure 2C), and in the non-sterilized condition, these values increased to (0,64 ± 0,03) day $^{-1}$ and (1,64 ± 0,02) g/L (Figure 2D). These results indicate that aeration enhanced the specific growth rate of S. salina M8 by nearly threefold, and biomass productivity by approximately twofold, compared to magnetic stirring, regardless of the culture medium. Importantly, S. salina M8 exhibited robust growth not only in BG-11 but also in untreated domestic wastewater. This finding has significant implications for the practical application of S. salina M8 in wastewater treatment, as it eliminates the need for sterilization and thereby offers substantial energy savings. Moreover, aeration significantly enhanced the specific growth rate and biomass productivity of S. salina M8. This effect can be attributed to the fact that aeration not only improves nutrient exchange between the culture medium and cyanobacterial cells but also accelerates the diffusion and dissolution of CO_2 from the atmosphere. This process increases the availability of bicarbonate ions (HCO_3^-), which serve as an essential inorganic carbon source for photosynthesis. In contrast, magnetic stirring merely maintains cell suspension within the culture medium without significantly enhancing CO_2 transfer from the air [C.V.T. Do, et al., 2021]. Based on these results, all subsequent experiments were conducted using non-sterilized domestic wastewater under aeration conditions, in order to maximize the growth and biomass accumulation of S. salina M8 under conditions that closely simulate real-world applications.

Table 4. Effect of pH on the growth of S. salina M8

Day		pH=5	pH=6	pH=7	pH=8	pH=9
Biomass (g/L)	0	0,68 ± 0,06	0,76± 0,06	0,87± 0,01	0,89± 0,08	0,61± 0,25
	2	0,78± 0,02	0,87± 0,03	0,98± 0,02	1,01± 0,01	0,88± 0,04
	4	0,81± 0,12	0,94± 0,06	1,29± 0,03	1,23± 0,06	1,02± 0,02
	6	0,97± 0,01	1,03± 0,05	1,46± 0,04	1,36± 0,01	1,06± 0,13
	8	1,15± 0,03	1,25± 0,02	1,59± 0,02	1,49± 0,05	0,98± 0,09
Growth rate μ (day^{-1})	0	0,26±0,02	0,24±0,03	0,22±0,05	0,18±0,04	0,16±0,12
	2	0,30±0,01	0,34±0,02	0,38±0,02	0,39±0,01	0,34±0,45
	4	0,31±0,01	0,36±0,32	0,50±0,14	0,45±0,02	0,48±0,13
	6	0,38±0,02	0,40±0,31	0,57±0,06	0,53±0,3	0,41±0,02
	8	0,45±0,01	0,48±0,05	0,62±0,01	0,58±0,01	0,38±0,02

Figure 5. Experiment on culturing S. salina M8 in domestic wastewater at different pH values

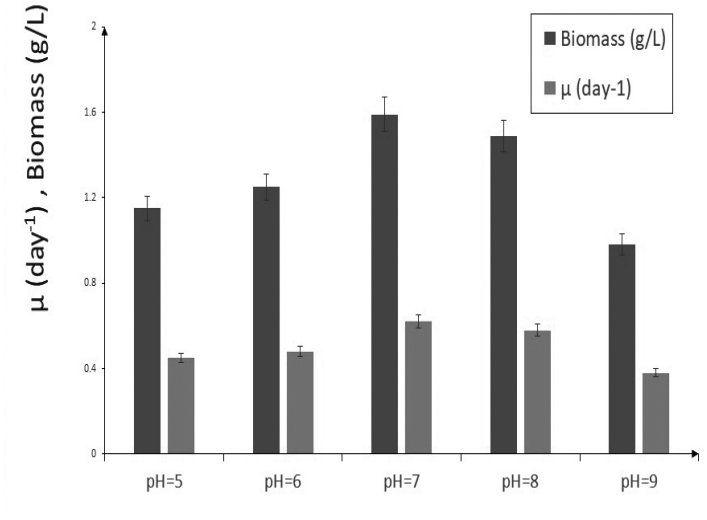

Figure 6. Specific growth rate and biomass of S. salina M8 in unsterilized domestic wastewater at different pH levels. Data were recorded on day 8 of the cultivation process under a light intensity of 4,500 Lux and a temperature of 27°C

3.3. Effect of pH on the growth of synechocystis salina M8 and the pollutant removal efficiency in domestic wastewater.

3.3.1. Effect of pH on the growth capacity of synechocystis salina M8

pH is an important factor that influences the photosynthetic process of microalgae by regulating the availability of dissolved carbon sources such as bicarbonate and CO_2 in the culture medium. In the cultivation of Synechocystis salina M8, pH directly affects nutrient uptake and growth rate, thereby playing a critical role in the efficiency of the cultivation process. The experiment was conducted in 1-liter Duran flasks at different pH values: 5, 6, 7, 8, and 9. The initial inoculum volume of S. salina M8 was set at 20% (v/v). Cultivation was carried out in non-sterilized domestic wastewater under aeration conditions (0.1 vvm), with continuous illumination at a light intensity of 4.500 Lux.

The results indicated that at neutral pH (pH = 7), S. salina M8 achieved the highest biomass of (1,59 ± 0,02) g/L on day 8, accompanied by the highest specific growth rate of (0,62 ± 0,01) day^{-1}. At pH 8, the biomass reached (1,49 ± 0,05) g/L, with a specific growth rate of (0,58 ± 0,01) day^{-1}. These results demonstrate that S. salina M8 grows best under neutral to slightly alkaline conditions. In contrast, under acidic conditions (pH = 5), biomass reached only (1,15 ± 0,03) g/L on day 8, and the specific growth rate remained the lowest among all treatments at (0,45 ± 0,01) day^{-1}. Similarly, under strongly alkaline conditions (pH = 9), although biomass increased over time, it only reached (0,98 ± 0,09) g/L on day 8,

Table 5. Pollutant concentrations in domestic wastewater before and after treatment with S. salina M8 at pH = 7

pH = 7.0	$N\text{-}NH_4^+$	TN	PO_4^{3-}	TP	COD
Before treatment (mg/L)	32,12 ± 0,42	36,12± 0,52	4,24 ± 0,15	5,2 ± 0,2	325,6 ± 0,3
After treatment (mg/L)	6,31 ± 0,22	7,23± 0,25	1,08± 0,05	1,27± 0,15	86,3± 0,5
Removal efficiency (%)	80,35± 0,33	79,98± 0,41	74,53± 0,51	75,58± 0,28	73,5± 0,12

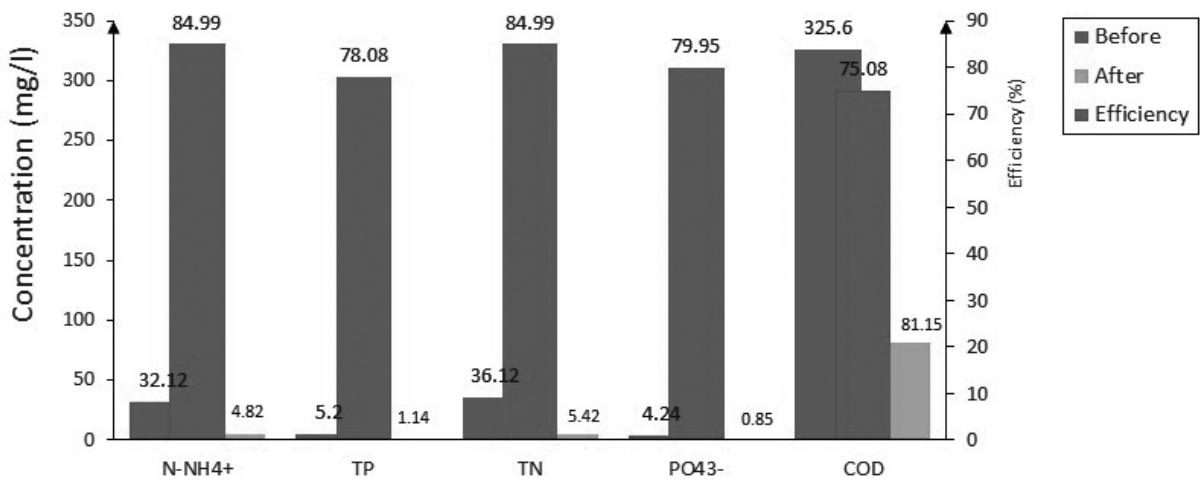

Figure 7. Concentrations of pollutants in domestic wastewater before and after treatment at pH 7, with 20% inoculum ratio, aeration at 0.1 vvm, and light intensity of 4,500 Lux

and the specific growth rate decreased from (0,48 ± 0,13) day $^{-1}$ to (0,38 ± 0,02) day $^{-1}$. These findings are consistent with those reported by Nguyen, B.T., et al., (2016), who observed optimal growth at pH 7.5, with a corresponding biomass of 0,355 ± 0,018 g/L and a growth rate of 0,136 ± 0,08 day $^{-1}$. (Nguyen, B.T., et al., 2016).

The pH of the culture medium for S. salina M8 tended to increase over time in all experimental conditions. This phenomenon can be explained by the photosynthetic process of the microalgae, in which CO_2 from the atmosphere dissolves into the medium and reacts as follows: $CO_2 + H_2O \rightarrow HCO_3^- + H^+$.

3.3.2. Evaluation of domestic wastewater treatment efficiency by S. salina M8 at pH = 7

The analysis results of pollutant concentrations and treatment efficiency by S. salina M8 at pH = 7 in domestic wastewater are presented in Table 5 and Figure 7.

The results showed that after 8 days of cultivation at pH 7, the concentrations of pollutants in the domestic wastewater significantly decreased. Specifically, the concentration of ammonium ($N\text{-}NH_4^+$) dropped sharply from (32,12 ± 0,42) mg/L to (6,31 ± 0,22) mg/L, corresponding to a removal efficiency of 80.35 ± 0.33%. This was the highest removal rate among the monitored parameters, reflecting the effective ammonium assimilation or biotransformation capability of S. salina M8. In addition, total nitrogen (T-N) was reduced from (36,12 ± 0,52) mg/L to (7,23 ± 0,25) mg/L, achieving a removal efficiency of 79,98 ± 0,41%, indicating a strong nitrogen uptake process, potentially through intracellular accumulation or biological nitrogen fixation. Similarly, $P\text{-}PO_4^{3-}$ and total phosphorus (T-P) exhibited removal efficiencies of 74,53 ± 0,51% and 75,58 ± 0,28%, respectively, demonstrating a high phosphorus removal capacity. For organic matter, COD decreased from (325,6 ± 0,3) mg/L to (86,3 ± 0,5) mg/L, corresponding to a removal efficiency of 73,5 ± 0,12%. Overall, S. salina M8 showed high simultaneous removal efficiencies of nitrogen, phosphorus, and COD under neutral pH conditions, indicating physiological stability and strong adaptability to domestic wastewater environments. These findings are consistent with the study by Doan Thi Oanh et al. (2020) on Chlorella vulgaris CNK, which achieved a 54% removal of $N\text{-}NH_4^+$ at pH 7 after 12 days of cultivation although lower than the efficiency observed for S. salina M8 in this study, highlighting the superior potential of the M8 strain for practical wastewater treatment application. (Doan Thi Oanh and partners, 2020).

3.4. Effects of C:N:P Ratio on growth and pollutant removal efficiency by S. salina M8

The experimental results investigating the effects of nutrient ratio C:N:P on the growth and pollutant removal efficiency in domestic wastewater by S. salina M8 after 8 days under the conditions of 20% (v/v) inoculum ratio, aeration at 0,1 vvm, and pH 7 are presented in Table 6 and Figure 9.

Table 6. Effect of C:N:P ratio on the biomass of S. salina

Day \ Ratio C:N:P		100:10:1	100:5:1	100:10:0.5	100:15:1
Biomass (g/L)	0	0,83±0,02	0,72±0,23	0,86±0,16	0,75±0,15
	2	1,16±,0,04	0,89±0,16	0,62±0,25	0,62±0,2
	4	1,47±0,01	1,17±0,24	1,17±0,45	0,95±0,23
	6	1,52±0,01	1,28±0,15	1,29±0,12	1,27±0,15
	8	1,64±0,05	1,46±0,02	1,26±0,02	1,12±0,01
Growth rate μ (ngày^{-1})	0	0,32±0,01	0,23±0,02	0,33±0,03	0,29±0,02
	2	0,45±0,02	0,34±0,02	0,24±0,15	0,24±0,01
	4	0,57±0,01	0,45±0,01	0,45±0,03	0,37±0,01
	6	0,59±0,02	0,50±0,01	0,50±0,25	0,49±0,02
	8	0,64±0,01	0,57±0,02	0,49±0,01	0,43±0,01

Figure 8. S. salina M8 experiments at different C:N:P ratios

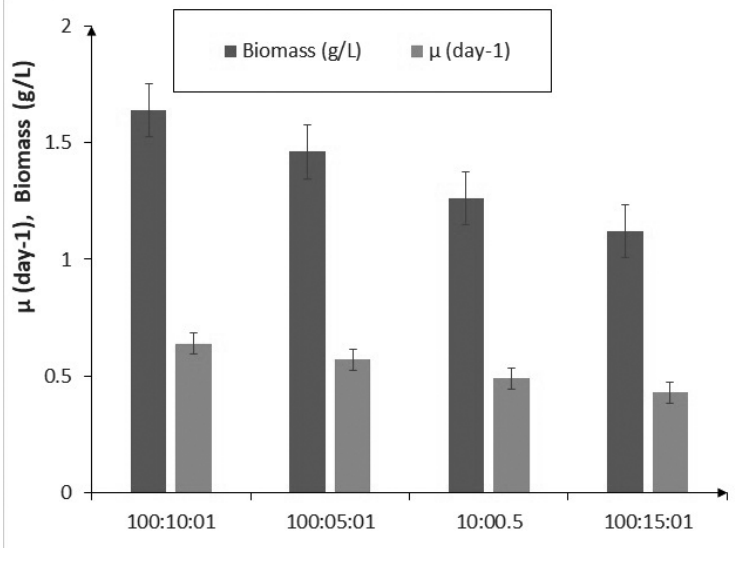

Figure 9. Specific growth rate and biomass of S. salina M8 in non-sterile wastewater at different C:N:P ratios. Data were measured on day 8 of the cultivation process under conditions of 4.500 Lux light intensity, 27°C temperature, pH 7, and aeration at 0,1 vvm

The results indicate a clear growth trend of S. salina M8 over the cultivation period across all experimental treatments. Notably, the treatment with a C:N:P ratio of 100:10:1 exhibited the highest biomass accumulation, increasing from (0,83±0,02) g/L at time point T0 to (1,64±0,05) g/L at T8. The specific growth rate (μ) also rose correspondingly from (0,32±0,01) day $^{-1}$ to (0,64±0,015) day $^{-1}$. This reflects the nutritional balance provided by this ratio, which optimally supports photosynthesis, carbon metabolism, and biomass synthesis in S. salina M8. In contrast, the C:N:P ratios of 100:5:1 and 100:10:0.5, while still supporting growth, resulted in lower biomass yields, reaching (1,46±0,02) g/L and (1,26±0,02) g/L at T8, respectively. The specific growth rates in these treatments were moderate, with μ = 0,57±0,02 and 0,49±0,01 day $^{-1}$. Nitrogen (100:5:1) or phosphorus (100:10:0.5) limitation likely constrained the synthesis of nucleic acids, proteins, ATP, and essential coenzymes required for growth. Interestingly, in the 100:15:1 treatment, despite a higher nitrogen content, biomass peaked at (1,27±0,15) g/L at T6 before slightly declining to (1,12±0,01) g/L at T8. This phenomenon is attributed to nitrogen excess, which not only fails to enhance growth but may exert inhibitory effects due to nutrient imbalance, possibly linked to ammonium accumulation or osmotic stress. These findings confirm that a balanced C:N:P nutrient ratio is a critical determinant of S. salina M8 growth performance. Phosphorus deficiency impairs nucleic acid and ATP synthesis, while nitrogen excess may alter intracellular pH, disrupt ion exchange, or lead to the accumulation of endogenous

Table 7. Pollutant concentrations in wastewater treated by S. salina M8 at different C:N:P ratios

Ratio C:N:P	NH_4^+ (mg/L)	TN (mg/L)	$P\text{-}PO_4^{3-}$ (mg/L)	TP (mg/L)	COD (mg/L)
T1 (100:10:1)	4,82± 0,11	5,42± 0,14	0,85± 0,10	1,14± 0,56	81,15± 0,16
T2 (100:5:1)	9,64± 0,21	10,84± 0,43	1,19± 0,20	1,66± 0,47	97,38± 0,23
T3 (100:10:0.5)	11,24± 0,24	12,64± 0,16	1,70± 0,16	2,18± 0,31	113,61± 0,85
T4 (100:15:1)	8,03± 0,31	9,03± 0,62	1,06± 0,08	1,56± 0,12	90,89± 0,16

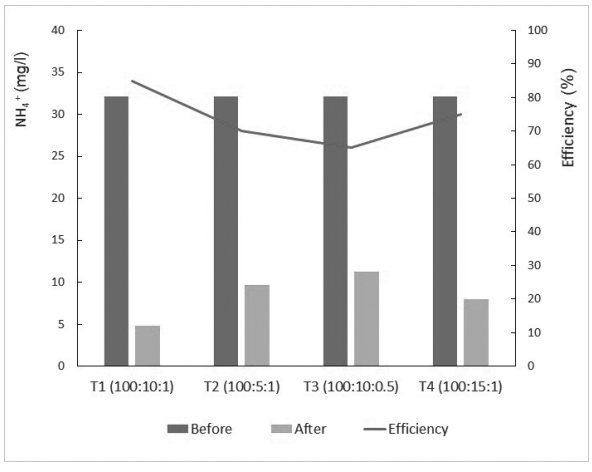

Figure 10. Ammonium nitrogen (N-NH4⁺) concentration in wastewater before and after treatment at different C:N:P ratios

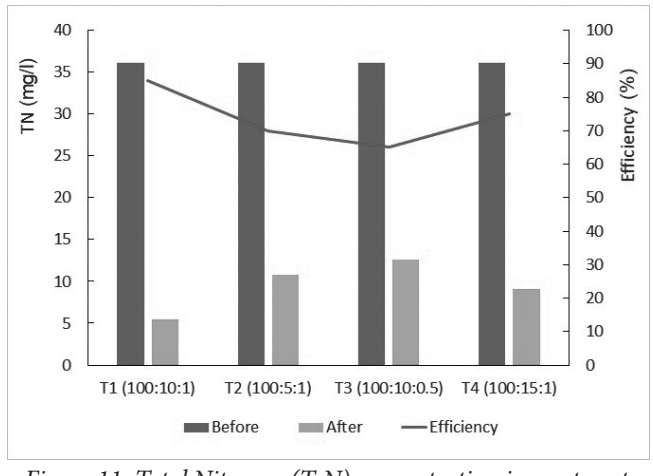

Figure 11. Total Nitrogen (T-N) concentration in wastewater before and after treatment at different C:N:P ratios

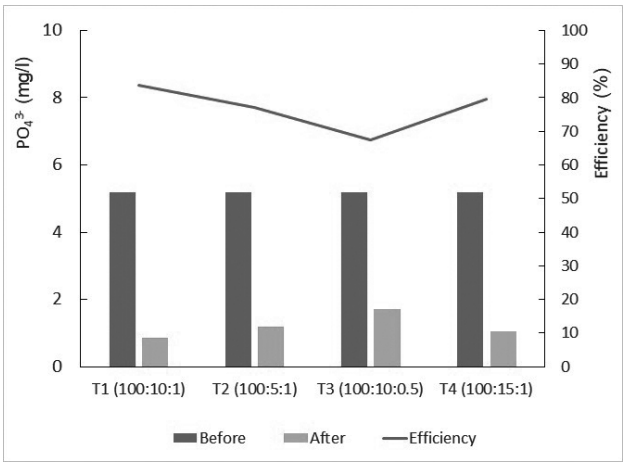

Figure 12. PO_4^{3-} concentration in wastewater before and after treatment at different C:N:P ratios

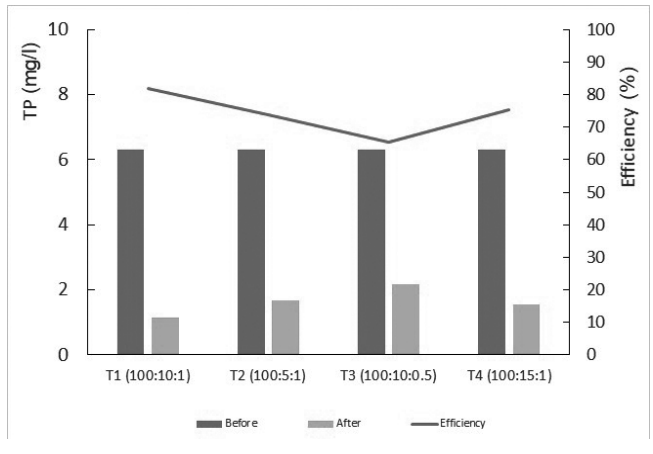

Figure 13. Total Phosphorus (T-P) concentration in wastewater before and after treatment at different C:N:P ratios

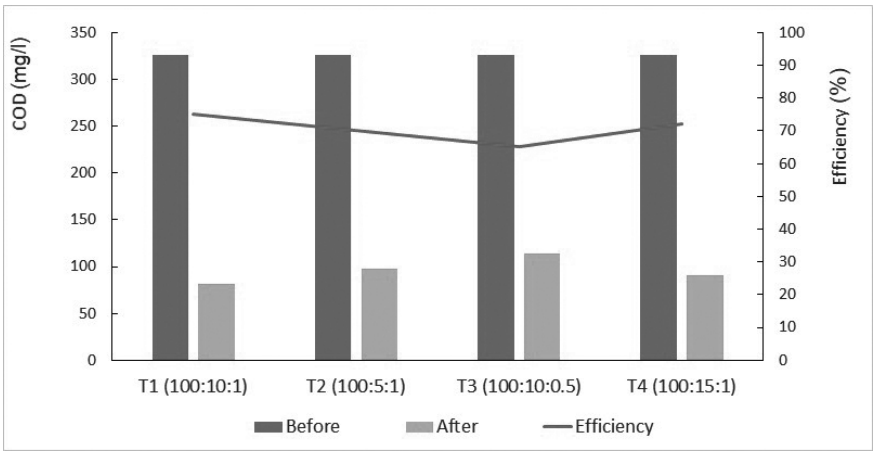

Figure 14. COD concentration in wastewater before and after treatment at different C:N:P ratios

Table 8. Pollutant removal efficiencies by S. salina M8 at C:N:P = 100:10:1

Ratio C:N:P = 100:10:1	$N\text{-}NH_4^+$	T-N	PO_4^{3-}	T-P	COD
Before (mg/L)	32,12 ± 0,42	36,12± 0,52	4,24 ± 0,15	5,2 ± 0,2	325,6 ± 0,3
After (mg/L)	4,82± 0,11	5,42± 0,14	0,85± 0,10	1,14± 0,56	81,15± 0,16
Efficiency (%)	84,99± 0,54	84,99± 0,62	79,95± 0,21	78,08± 0,2	75,08± 1,20

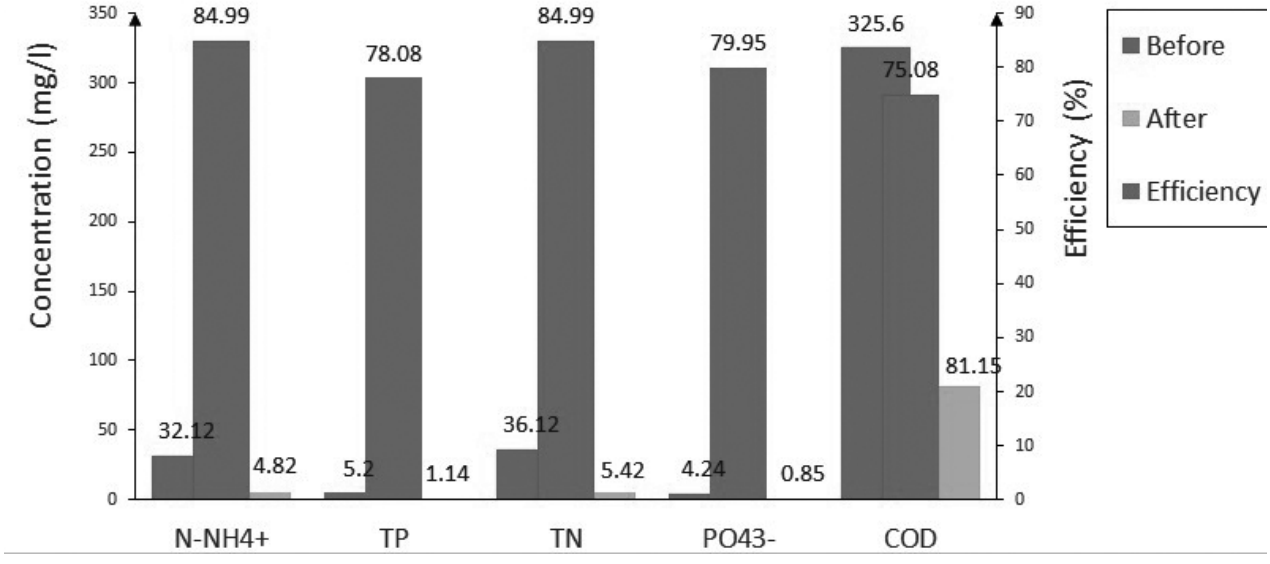

Figure 15. Pollutant concentrations before and after treatment at C:N:P = 100:10:1

inhibitors. These results are consistent with the study by Gonçalves et al. (2016), in which S. salina cultured in wastewater supplemented with 7% CO_2 achieved the highest average biomass productivity of (0,173 ± 0,009) g/L/day after seven days of cultivation. Although the nutrient conditions differ, the trend of optimal growth in CO_2 - rich and nutritionally balanced environments parallels the 100:10:1 treatment in this study.

The results showed that after 8 days of cultivation at a C:N:P ratio of 100:10:1, the concentrations of $N\text{-}NH_4^+$, total nitrogen (TN), total phosphorus (TP), phosphate (PO_4^{3-}), and chemical oxygen demand (COD) in the wastewater decreased significantly, indicating the high overall treatment efficiency of S. salina M8. Specifically, both $N\text{-}NH_4^+$ and TN reached a removal efficiency of 84,99 ± 0,54%, demonstrating the strain's capability to effectively eliminate both inorganic and organic nitrogen forms. PO_4^{3-} and TP were also removed with efficiencies of 79,95 ± 0,21% and 78,08 ± 0,20%, respectively. COD levels decreased from 325,6 ± 0,3 mg/L to 81,15 ± 0,16 mg/L, corresponding to a removal rate of 75,08 ± 1,20%, thereby meeting the discharge standard specified in QCVN 14:2008/BTNMT (column B). These findings are consistent with those reported by Nattawut Krasaesueb et al. (2019), where the strain Synechocystis sp. cultivated in ammonium and phosphate-rich wastewater achieved nutrient removal efficiencies of 96.99% for phosphate, 80,10% for nitrate, 67,90% for nitrite, and 98,07% for ammonium (N. Krasaesueb et al., 2019). Similarly, the results align with the study by Li et al. (2024), in which Chlorella vulgaris was co-cultivated with aerobic bacteria for the treatment of mixed wastewater at a C:N ratio of 15:1. This system achieved the highest removal efficiencies for COD, NH_4^+-N, and TP, which were 60,89 ± 1,80%, 43,38 ± 1,00%, and 68,55 ± 0,59%, respectively (Li, R et al., 2024).

Thus, the combination of a balanced C:N:P ratio of 100:10:1 with optimized culture conditions including 20% (v/v) algal inoculum, continuous aeration at 0,1 vvm, light intensity of 4.500 Lux, pH 7, and temperature at 27°C created a biologically favorable environment that enabled S. salina M8 to grow effectively, accumulate biomass, and simultaneously remove nitrogen-, phosphorus-containing compounds, and organic matter from wastewater. The ability to achieve removal efficiencies greater than 80% for most parameters under non-sterile wastewater conditions further confirms the potential of this strain for application in sustainable biological wastewater treatment systems.

4. CONCLUSION

This study conducted a preliminary investigation into the growth and domestic wastewater treatment efficiency of S. salina M8 in various nutrient environments, including BG-11 medium and domestic wastewater. The results demonstrated that S. salina M8 grew well in both BG-11 and domestic wastewater under aerated conditions. Biomass productivity reached 1,34 g/L in non-sterile BG-11 medium and 1,64 g/L in domestic wastewater under identical conditions: pH 7, light intensity of 4.500 Lux, a C:N:P nutrient ratio of 100:10:1, and continuous aeration at 0,1 vvm over 8 days. Pollutant removal efficiencies were as follows: N-NH_4^+ (85%), total nitrogen (85%), phosphate (PO_4^{3-}) (79,95%), total phosphorus (78,08%), and chemical oxygen demand (COD) (75,08%). The treated wastewater met the discharge standards specified in QCVN 14:2008/BTNMT, column B. Although the findings were obtained at laboratory scale, further research and practical implementation of S. salina M8 in small-scale wastewater treatment systems such as those for households, residential areas, schools, or public institutions are needed. Moreover, future studies should focus on reducing operational costs, and recovering and reusing S. salina M8 biomass. This includes the extraction and purification of high-value products such as polyhydroxyalkanoates (PHA), biofertilizers, biofuel feedstock, or phycocyanin, thereby contributing to the development of a sustainable green and circular economy■

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INCLUSIVE GREEN, DIGITAL TRANSFORMATION FOR SUSTAINABLE DEVELOPMENT IN VIETNAM

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Abstract

Sustainable development requires linking economic development with social progress and environmental protection. Resolution 39-NQ/TW on improving the efficiency of management, exploitation, use and promotion of economic resources, including human, material and financial resources, plays an important role in the green transformation, digital transformation and inclusive transformation so that Vietnam can continue to participate in global trade and investment activities, integrating sustainable production and consumption into the global supply chain.Using flexible economic tools and market-based solutions instead of rigid administrative management and criminal procedures are the basis for Vietnam to move from a traditional society to a pre-take-off stage, and to take off stage according to the Rostow economic growth model, towards a modern industrial stage, and a modern post-industrial society in the future.

Keyword: *Inclusive green, Digital transformation, Sustainable Development.*

JEL Classification: *F63, H23, O33, O44, Q01.*

Received: *1st May 2025****; Revised:*** *26th May 2025;* ***Accepted:****16th June 2025.*

1. OVERVIEW OF GREEN TRANSFORMATION, DIGITAL TRANSFORMATION, INCLUSIVE TRANSFORMATION FOR SUSTAINABLE DEVELOPMENT

The world is facing three planetary crises: climate change, environmental pollution, and biodiversity loss. Global investors are increasingly interested in investing in assets that have a positive impact on the environment, in order to meet voluntary and mandatory ESG (Environmental, Social, and Governance) standards. Vietnam has committed to implementing the National Green Growth Strategy to 2030, with a vision to 2050, in the context of increasing international requirements for environmental protection and sustainable development. Vietnam is committed to building a green, circular economy, ensuring water resource security, developing sustainable agriculture, and increasing the resilience of ecosystems and societies to the negative impacts of natural disasters and climate change. The strategy for 2030 will focus on reducing water and land degradation, ensuring water supplies for key economic sectors, and transforming agriculture towards climate-smart agriculture. Forest cover will also be maintained at at least 42%, while the area of terrestrial and marine nature reserves will continue to expand. By 2050, the goal of effectively managing natural resources, protecting biodiversity, and ensuring that all people have access to clean, safe water and health care services will be fully achieved.

Green transformation, digital transformation, and inclusive transformation are the foundations for improving the efficiency of management, exploitation, use, and promotion of green human resources, green material resources, and green financial resources for sustainable development, realizing Vietnam's commitment to zero net emissions by 2050 at COP26. Green transformation, digital transformation, and inclusive transformation allow for resource management from the center of the earth to the end of the atmosphere. National resource management based on spatial data is based on national geography, the national spatial data infrastructure NSDI (National Spatial Data Infrastructure) and the national cadastral database NDCD (National Digital Cadastral Database). All national resources are stored with characteristics according to traditional databases and coordinates according to the GIS (Global Information System) spatial database. The national sustainable development strategy needs to be established, implemented, checked, inspected, and monitored based on statistics, inventories, accounting and auditing according to the integrated land use landscape management method, applying multi-layer thematic mapping technology to national resource management.

National sovereign territory includes underground layers, land areas, sea areas, continental shelves, airspace and atmospheric layers. Applying digital transformation to integrated landscape management of national land use to allocate land according to space of use (underground, ground and air) for socio-economic

development, national defense, security, environmental protection, biodiversity and climate change adaptation goals based on land potential and land use needs of sectors and fields for each socio-economic region and administrative units. Multi-layer thematic map technology is built on the basis of exploiting digital transformation technologies that are popular in the world today: i) Applying big data technology to store data in many independent data layers implemented by sector management ministries, specialized management agencies and local areas managing the area; ii) Applying artificial intelligence (AI) and machine learning to approve and confirm spatial database information collected through satellites, drones, street view cameras and information provided by public service users, updated daily; iii) Applying cloud technology so that the state can centrally manage data and people can access it anytime, anywhere, using a unified citizen identification numbers; iv) Apply blockchain technology to store data over time and record adjustments on the database information system. Administrative procedures can be carried out and public data can be accessed according to citizen identification numbers.

2. GREEN TRANSFORMATION, DIGITAL TRANSFORMATION, AND INCLUSIVE TRANSFORMATION ARE REQUIRED FOR VIETNAM TO CONTINUE PARTICIPATING IN THE GLOBAL TRADE AND INVESTMENT SYSTEM

Vietnam has participated in a number of new generation FTAs, notably the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), with required sustainable and inclusive measures. Sustainable and inclusive development is the new rules of the game in trade and investment, a mandatory requirement to comply with climate, environment, biodiversity, trade and investment commitments, and a condition for Vietnam to be able to integrate into the global food system, energy security, finance, trade, investment and supply chain systems. From January 2023, the Non-Financial Reporting Directive (NFRD) came into force, requiring large companies to disclose information about the environmental impact of their business activities. The Corporate Sustainability Reporting Directive (CSRD) extends sustainability reporting requirements to listed small and medium-sized enterprises. The Corporate Sustainability Due Diligence Directive (CSDDD) requires companies to monitor and report sustainability risks in their supply chains. The European Union Deforestation Regulation (EUDR) requires companies exporting products to the EU to ensure that their products have not been deforested after 31st December 2020. Under the Carbon Border Adjustment Mechanism (CBAM), companies producing and exporting products such as steel, cement, aluminium, and fertilisers to the EU must measure and report their carbon emissions from 1st October 2023, and buy carbon credits to offset their emissions from 2026.

Vietnam's major trading partners have all issued policies on emission reduction to fulfill their commitments on climate goals. The European Union (EU) has implemented an Emissions Trading Scheme (ETS) to reduce emissions by 55% from 1990 levels by 2030 and extend its carbon policy framework by 2040, aiming to achieve net zero emissions by 2050. The United States aims to reduce emissions by 50-52% from 2005 levels by 2030 through its national emissions reduction program and will increase the adoption of clean energy technologies by 2040, with the ambition to achieve net zero emissions by 2050. China, with a carbon trading scheme, is expected to peak emissions by 2030 and reduce emissions intensity by 60-65% from 2005 levels by 2040, aiming to achieve net zero emissions by 2060. The United Kingdom is committed to reducing emissions by 68% from 1990 levels by 2060. 2030 and is investing heavily in renewable energy and sustainable infrastructure, with a goal of achieving net zero emissions by 2050. Canada aims to reduce emissions by 40-45% from 2005 levels by 2030 through a carbon tax program and increased development of renewable energy technology to achieve net zero emissions by 2050. Japan, with its climate action plan, will reduce emissions by 26% from 2013 levels by 2030, and focus on increasing renewable energy capacity to achieve net zero emissions by 2050.

The current global context shows that the need to respond to climate change has become an irreversible trend, with profound impacts on all areas such as economics, politics, diplomacy and national security. With specific goals, Vietnam aims to reduce greenhouse gas emissions and achieve net zero emissions by 2050, a task that is not only mandatory for sustainable development but also an opportunity to promote economic restructuring in an environmentally friendly direction and enhance competitiveness, in line with the requirements of the Paris Agreement and global trends after the COP26 Conference. Vietnam has great potential for renewable energy, especially solar

Emission reduction roadmaps of Vietnam's trade and investment partners

Nation	Policy	Target by 2030	Target by 2040	Target by 2050
European Union (EU)	- Emissions Trading System (ETS)	- Reduce emissions by 55% compared to 1990	- Expanded carbon policy framework	- Achieve net zero emissions
	- Carbon tax directive	- Developing carbon tax systems in member states	- Increase carbon tax for key sectors	- Building a comprehensive carbon tax system
USA	- National Emission Reduction Program	- Reduce emissions by 50-52% compared to 2005	- Increase the application of clean energy technology	- Achieve net zero emissions by 2050
	- Emission management from industries	- Implement stricter regulations for the industry	- Strengthening the development of renewable energy	- Reduce emissions in all sectors
China	- Carbon trading mechanism	- Peak emissions by 2030	- Reduce emission intensity by 60-65% compared to 2005	- Achieve net zero emissions by 2060
	- Invest in renewable energy	- Increase renewable energy capacity to 1,200 GW	- Increase the proportion of renewable energy in total energy consumption	- Achieve 80% renewable energy ratio
United Kingdom	- Emissions trading mechanism	- 68% reduction in emissions compared to 1990	- Implement additional emission reduction measures	- Achieve net zero emissions by 2050
	- Clean energy investment support program	- Invest £20bn in renewable energy and sustainable infrastructure	- Increase investment in green technology	- Building a completely sustainable infrastructure
Canada	- Carbon tax program	- Reduce emissions by 40-45% compared to 2005	- Strengthen carbon taxes and other emissions reduction policies	- Achieve net zero emissions by 2050
	- Investing in green technology	- Strengthening the development of renewable energy technology	- Invest in research and development of new technology	- Promote investment in emission reduction technology
Japan	- Climate Action Plan	- 26% reduction in emissions compared to 2013	- Strengthening the development of renewable energy technology	- Achieve net zero emissions by 2050
	- Invest in renewable energy	- Increase renewable energy capacity to 36-38% of total consumption	- Improve renewable energy capacity	- Building a sustainable energy system

Source: Author's compilation. Goals and policies may vary according to the actual situation and commitments of each country or region

energy, wind energy and biomass. The development of renewable energy helps reduce dependence on increasingly depleted fossil energy sources, causing environmental pollution and affecting climate change. Renewable energy not only provides a sustainable source of energy but also reduces greenhouse gas emissions, thereby contributing to global efforts to combat climate change.

3. SOLUTIONS TO MOBILIZE GREEN HUMAN RESOURCES, GREEN MATERIAL RESOURCES, GREEN FINANCE FOR SUSTAINABLE DEVELOPMENT IN VIETNAM

On October 1st, 2021, the Prime Minister issued Decision 1658/QD-TTg, approving the National Strategy on Green Growth for the 2021-2030 period, with a vision to 2050. This strategy aims to promote

economic restructuring associated with growth model innovation, increasing competitiveness and resilience to external shocks. Green growth is an important method for sustainable development, contributing to reducing greenhouse gas emissions and moving towards a carbon-neutral economy. This strategy puts people at the center, encourages responsible lifestyles, improves quality of life and resilience to climate change. Green growth relies on institutions, modern science and technology and high-quality human resources, orienting investment in advanced technology, digital transformation and sustainable infrastructure. The National Climate Change Strategy to 2050, approved under Decision No. 896/QD-TTg dated July 26th, 2022, demonstrates Vietnam's strong commitment to responding to the enormous challenges posed by climate change. Decision No. 215/QD-TTg dated March 1st, 2024 of the Prime Minister of Vietnam approving the National Energy Development Strategy to 2030, with a vision to 2045, sets out important goals in ensuring energy security and sustainable development. Power Master Plan VIII emphasizes the importance of promoting renewable energy projects such as solar power, wind power and small hydropower, while gradually reducing dependence on coal and gas power projects to limit greenhouse gas emissions and negative impacts on the environment. Decision No. 749/QD-TTg approving the "National Digital Transformation Program to 2025, with a vision to 2030" sets out a vision for Vietnam to become a digital, stable and prosperous country, and identifies the goals for developing a digital government, digital economy and digital society. Specifically, by 2025, the program sets a target of 80% of online public services reaching level 4, 100% of reporting and statistical indicators being connected and sharing data on the Government Reporting Information System. By 2030, this target will be expanded, with 100% of online public services and 100% of assignments at the ministerial and provincial levels being processed online. The program emphasizes the role of awareness in digital transformation, considering people as the center and promoting the development of digital platforms and digital infrastructure as breakthrough solutions to reduce costs and increase efficiency in management and operation activities.

Green workforce plays a key role in the transition to an environmentally friendly economy, focusing on industries such as renewable energy, waste treatment, sustainable agriculture and clean manufacturing. The workforce needs to be equipped with the necessary knowledge and skills to apply advanced technological solutions to minimize negative impacts on the environment, while developing new industries with high added value and contributing to reducing greenhouse gas emissions. In addition, digital transformation is also opening up many opportunities for Vietnam, especially in the context of the Fourth Industrial Revolution, which is promoting strong digitalization in all fields. Human resources in this field need to have high expertise in information technology, data, artificial intelligence (AI), and other emerging technologies. Human resources in this field require not only professional skills but also a deep understanding of social policies and laws, especially those related to gender equality, labor rights, and a safe working environment. The major challenge for Vietnam today is to ensure that the workforce can adapt to rapid changes in the labor market, helping the country not only keep up but also lead in green, digital, and inclusive transformation.

Vietnam is facing increasing water scarcity and pollution due to the impacts of climate change, urbanization and population growth. Investing in green infrastructure is an important factor in building environmentally friendly structures such as energy-efficient buildings, modern public transport systems that reduce emissions, and efficient wastewater and waste treatment infrastructure, facilitating improvements in living environment quality, promoting green and digital economic growth through creating new jobs and encouraging the development of green industries. Water management using an integrated, landscape approach focuses on the use of advanced technologies and sustainable management methods to conserve water resources and improve water quality by building water reuse systems, efficiently using water resources in agricultural and industrial production, and protecting freshwater ecosystems. Vietnam has introduced policies to strictly manage the exploitation and use of groundwater, while encouraging businesses and local communities to participate in water resource protection programs and develop infrastructure such as reservoirs, dams and sustainable water distribution systems. Centralized, circulating, low-emission wastewater treatment infrastructure is an integral part of the wastewater management strategy towards sustainable development and climate change mitigation in Vietnam. Emission reduction measures in wastewater treatment include optimizing biological

Digital transformation not only modernizes the economy but also provides powerful tools to promote green growth

treatment processes, improving treatment technology to reduce nitrogen and phosphorus in wastewater, using anaerobic systems combined with measures to recover and reuse methane gas as an energy source, instead of letting this gas escape into the air, helping to convert emissions into clean energy for the plant.

The big challenge for Vietnam is to mobilize enough green capital to train green human resources and implement green infrastructure projects on a national scale, especially in the context of the economy being under pressure from rapid development and serious environmental issues. Opportunities to mobilize climate finance and green finance from international organizations, investment funds, the financial system, multinational companies and development partners for green transformation, digital transformation, and water resource management in Vietnam are opening up great potential to promote sustainable development and achieve emission reduction targets. These funds are dedicated to projects with clear goals of mitigating the impacts of climate change, improving energy and water efficiency, and promoting digital technology solutions in resource management. Global climate funds such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF) are opening up funding opportunities and technical assistance for Vietnam to invest in green infrastructure, renewable energy, and sustainable water management projects. Investment funds can provide abundant financial resources for green projects, helping to realize environmental protection and sustainable development initiatives. The financial system, through the provision of financial products such as green bonds and green credit, can support businesses in deploying clean technology solutions. Vietnamese businesses, especially in the energy, technology and infrastructure sectors, can access this capital by meeting standards on sustainable development and environmental transparency. Green bond issuance has been successfully implemented in many countries around the world, and Vietnam also has the potential to apply this model to mobilize capital for digital transformation projects combined with water resource protection, pollution reduction and carbon emissions.

Integrating green finance into economic development strategies will create strong momentum for sectors, from agriculture, industry to services, to adopt sustainable production models, reduce emissions and optimize resources. The Vietnamese government needs to develop a green taxonomy, play an important role in promoting the legal framework and facilitating the development of the green finance

market, including the development of digital financial infrastructure, environmental monitoring and assessment systems, to enhance transparency and social responsibility in the use of climate finance.The strategy promotes the development of financial mechanisms and carbon markets to encourage investment shifts to low-emission economic activities, creating conditions for businesses and individuals to actively participate in climate protection and building a sustainable and prosperous Vietnam in the future.

People often act on personal motives, so the best way to mobilize and exploit the country's resources is to base on the design of institutional arrangements and create financial incentives so that personal interests coincide with national interests, motivating people to pursue personal interests while simultaneously contributing to national interests. In the private sector, the performance-based salary model is the foundation for building a self-conscious working mechanism. In financial and budget management, the government regulates income inequality through taxes, improving people's quality of life through an effective public service system. Implementing results -based budget management to motivate people and businesses to develop.

Digital transformation and the use of unified personal identification codes according to the Law on Citizen Identification are the first steps for people to use unified public services such as: Social insurance, health insurance, tax codes, population management, electronic medical records, online student codes, civil servant and public employee codes, public service user codes, bank accounts, treasury to fulfill financial obligations to the State, pay fines, collect fees, road fees, parking, etc. In the green and digital era, the most valuable asset is the user. It is necessary to develop personal identification codes for public service users, develop the digital ecosystem and Vietnamese social networks to exploit the resources of the population of more than hundred millions of people in Vietnam.

It is necessary to apply digital transformation to change the way of managing the state budget in spatial criteria, using multi-layer thematic maps to improve the effectiveness of state budget management. The state budget needs to be managed through results (performance-based budgeting) instead of controlling expenditure items (line-item budgeting); implementing medium-term expenditures according to the development strategy; rolling annually to ensure flexibility. Both concurrent and investment expenditures must implement medium-term expenditures in line with the development strategy, managed by outputs and outcomes. Digital transformation allows the management of the state budget by spatial criteria using multi-layer thematic maps to identify areas lacking in schools, hospitals, transport infrastructure, culture, sports, or with high unemployment rates, which are prioritized for budget allocation, resource, finance, and investment based on statistical data, inventory, and spatial accounting.

Digital transformation is not only a trend but also an essential tool in implementing green transformation and sustainable, inclusive development. Through the application of digital technology, organizations and businesses can optimize production processes, manage resources more effectively and minimize negative impacts on the environment. Digital transformation also promotes the creation of environmentally friendly products and services, supports sustainable economic development and creates social value. By combining technology and sustainable development strategies, we can build a greener future, while ensuring fairness and inclusion for all members of society■

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DEVELOPING A CLOSED-LOOP WATER MANAGEMENT SYSTEM WITH CLIMATE CHANGE IMPACTS ADAPTATION IN BEN TRE PROVINCE

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Abstract

The closed-loop water management model is a system for managing water resources through reuse and circulation, aimed at minimizing loss, pollution, and waste (Grigg, 2008; GWP, 2000). At the same time, it helps address water scarcity issues in Ben Tre amid increasingly complex and unpredictable climate change impacts. Therefore, it is essential to orient water resource management solutions for surface water along both short-term and long-term routes (Butterworth et al., 2010). By using synthesizing, analyzing, and inheritinginformation and data from various sources, surveys, and monitoring activities of the province to utilize this model to address Ben Tre's current problems. This model enables the spatial utilization and exploitation of available water components to meet three requirements: total water volume, the capacity for extraction and use across multiple needs, and quality assurance of water sources for each usage purpose (domestic usage, industrial production, agricultural production, and aquaculture)(Biswas, 2008; Srinivasan et al., 2012). Therefore, in addition to reviewing, evaluating, and analyzing water mangagement related infrastructure systems (such as hydraulic infrastructure), salinity monitoring and warning infrastructure, and updating irrigation and water resource planning for each region, it is essential to propose an integrated surface water resource management model for Ben Tre, along with the necessary tools for effective practical implementation.

Keywords: *Ben Tre, closed-loop water management system, climate change.*

JEL Classifications: *Q25, Q54, Q55.*

Received: *26th May 2025****; Revised:*** *12th June 2025****; Accepted:*** *27th June 2025.*

1. INTRODUCTION

Surface water resources (SWR) in Ben Tre Province of Vietnam hold exceptional significance for the province's livelihoods, production, and environment. They provide water for treatment plants that supply domestic, industrial, and service sectors; irrigation for agricultural production; water for livestock and aquaculture. These resources are also a key factor in promoting inland waterway transportation and the development of garden-based eco-tourism. Moreover, they serve as habitats for aquatic species and play an essential role in maintaining the ecological health of both aquatic and terrestrial ecosystems.

SWR in Ben Tre Province mostly come from Tien river, which branches to four sub-river including My Tho, Ba Lai, Ham Luong and Co Chien river. This kind of branches represent a fan-like arrangement of rivers distribution, and embracing the three strips of islets that make up Ben Tre. All of them flow in a northwest–southeast direction and empty into the sea. These four rivers play a very important role in the economic and cultural life of the province's residents.

Due to the impact of climate change, during the dry season, saltwater from the East Sea increasingly intrudes deeper inland, affecting more than two-thirds of the province's total area. This salinization contaminates most rivers, canals, and water sources, leading to degradation and pollution that severely affect people's lives, especially their access to clean water. Groundwater at the depth between 40 – 120 meters and over 350 – 450 meters in Ben Tre is only found in a few communes located in the central area of Thanh Phu District and part of northern Chau Thanh District. However, the water quality is only marginally suitable for domestic use, as salinity levels range from 0,35 to 0,8‰, while the Ministry of Health's standard is just 0,3‰. According to the Ben Tre Center for Rural Clean Water and Environmental Sanitation, due to climate change, the province is currently facing a severe shortage of freshwater. Moreover, during the dry season, saltwater intrudes deeper and more aggressively into inland areas, as the internal irrigation canal system remains incomplete.

From the issues outlined above, it is obvious that Ben Tre Province is currently facing, and will

continue to face, significant water resource challenges. One major concern is the province's dependence on upstream water sources, which are increasingly being exploited. Moreover, water resources in the region are unevenly distributed in both space and time, in terms of both quality and quantity, leading to water scarcity and shortages during the dry season. In addition, the exploitation and usage of water resources remain inefficient and unsustainable, resulting in the depletion of water supplies, while water use efficiency is still quite low. Meanwhile, demand for water continues to increase, even as water sources face growing risks of pollution, degradation, scarcity, and exhaustion. Therefore, it is essential to conduct research and assessments on the current status of surface water exploitation and use across the province. Based on these findings, more focus and appropriate solutions should be proposed to manage and utilize water resources. These solutions should be under a closed-loop water management model due to current hydraulic systems and managing schemes of the province, this model should be a better way to ensuring water security and protecting the livelihoods of local residents.

2. RESEARCH SUBJECTS AND METHODS

2.1. Research subjects: Surface water resources in Ben Tre Province of Vietnam and applying closed-loop water management model is a system for managing water resources.

2.2. Method of synthesizing and analyzing information and data: The research team collected information and data on the flow rates of major rivers in Ben Tre Province to support the water resource assessment; rainfall data provided by the meteorological and hydrological agency; data on water usage demand and the current status of surface water exploitation in Ben Tre; and legal documents issued by both the central government and Ben Tre Province regarding surface water resources.

2.3. Inheritance method: This method involves inheriting and compiling the results of previous surveys and monitoring activities related to surface water resources in the province, as well as findings from relevant research projects, scientific papers, and studies both domestic and international. These serve as a foundation for assessing water resources and proposing solutions for remediation and the rational, sustainable distribution and use of water.

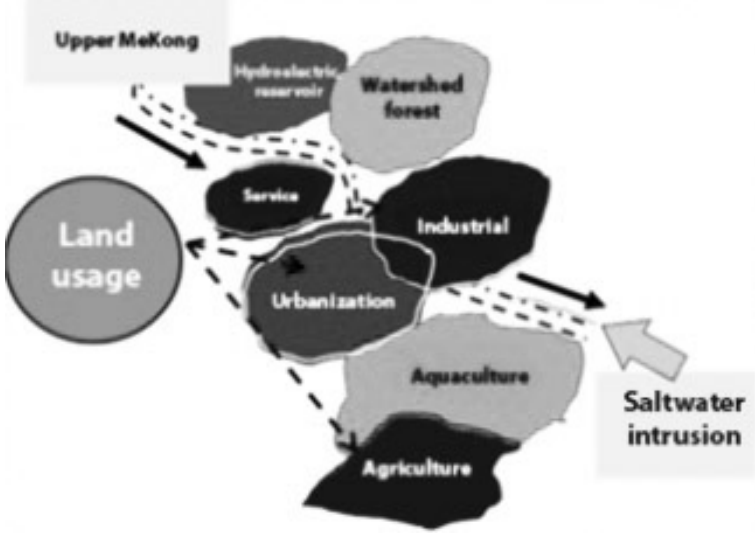

Figure 1. Challenges to surface water resources in Ben Tre

3. RESULTS AND DISCUSSION

3.1. Challenges facing surface water resources in Ben Tre Province

In the course of increasingly climate change impacts in the Mekong Delta, SWR are among the most heavily affected. Freshwater areas are shrinking due to intensified saltwater intrusion, driven by rising sea levels and declining rainfall. Clean water availability is also diminishing as a result of pollution from industrial, agricultural, and domestic activities. Additionally, the total volume and flow rates of major rivers in the province have decreased due to upstream activities along the Mekong River. In addition, both the quality and quantity of SWR in general, and the available water sources in Ben Tre in particular, have been and are being increasingly affected by the processes of urbanization and industrialization. These developments have led to a growing demand for water for domestic use, services, agricultural production, and aquaculture (Figure 1).

The orientation of SWR management solutions must be implemented through both short-term and long-term roadmaps (Schreier et al., 2014; Suhardiman et al., 2015). In the long term, the adoption of an integrated water resource management approach requires a clearly defined roadmap beyond 2030, with the synchronized implementation of key policy groups. Under this roadmap, SWR in Ben Tre Province will be sustainably managed, and rationally exploited and used for each water user group. In the short period from 2025 to 2030, ensuring the availability and stability of SWR must be feasible in terms of: The total volume of water available for various uses; and the spatial coverage to meet

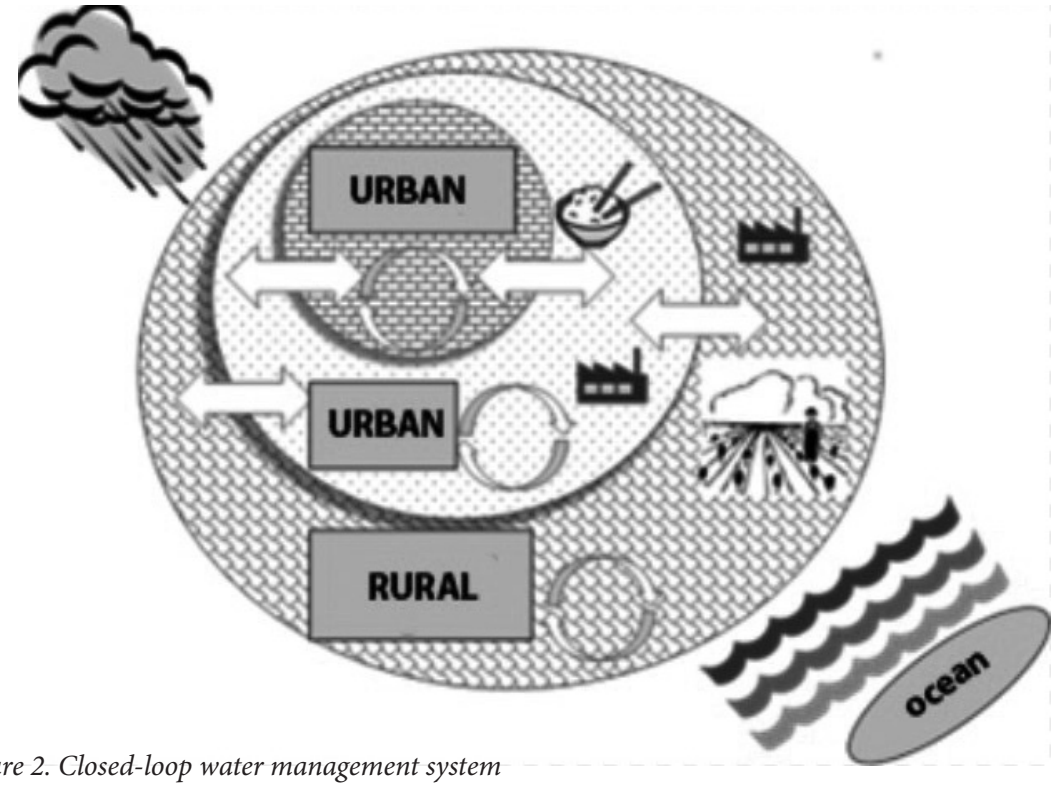

Figure 2. Closed-loop water management system

demands in both urban areas (for domestic, industrial, and service needs) and rural areas (for domestic and agricultural production needs).

3.2. Closed-loop water management system

The proposed closed-loop water management model can be considered a suitable solution for Ben Tre Province. The principles of this model are illustrated in Figure 2.

The components of water resources and the entities (or activities) that exploit and use water in Ben Tre are viewed as part of a closed-loop, intra-provincial water cycle, including: (i) Rainwater – A component of the natural hydrological cycle, which contributes to surface runoff through rivers, canals, and streams, with a portion infiltrating geological layers to form groundwater; (ii) Surface water – One of the three main components of the water cycle. The surface runoff generated by rainfall over land use areas constitutes the SWR of the province. This is the primary source for meeting water demands in agricultural production, aquaculture, industrial activities, services, and domestic use. (iii) Groundwater – The third component of the water cycle. A large portion of rainwater, after forming surface runoff, naturally infiltrates geological layers to recharge groundwater. The groundwater zones found in the coastal sand dune areas of Ben Tre have been formed through this natural process. (iv) Seawater – A form of surface water within the natural hydrological cycle, primarily serving aquaculture activities in coastal areas.

The key point of the model lies in its approach to utilizing and exploiting the available water components distributed across space, ensuring the fulfillment of three main requirements: (i) Total water volume (availability of water resources); (ii) The capacity to extract and use water for various needs; and (iii) Assurance of water quality for each specific use. To implement the closed-loop water management model, the essential components that must be put into practice immediately include: Recycling and reusing water sources; collecting and using rainwater; combining the exploitation of surface water and groundwater; and completing the water quality monitoring and management network.

3.2.1. The circulation and reuse of water resources

The recycling and reuse solution must be implemented for specific water users and purposes, as follows:

For urban areas (such as Ben Tre city, towns, and communes): Domestic wastewater, once treated to meet discharge standards (Category A), can be reused for irrigating parks, green spaces, and buffer zones. This solution is particularly suitable during the dry season in the Mekong Delta, when saltwater intrusion into SWR tends to intensify. Additionally, it may be considered for aquaculture activities in peri-urban areas, such as pond farming (e.g., fish, eels).

For industrial zones and clusters: Treated wastewater from food processing industries can be

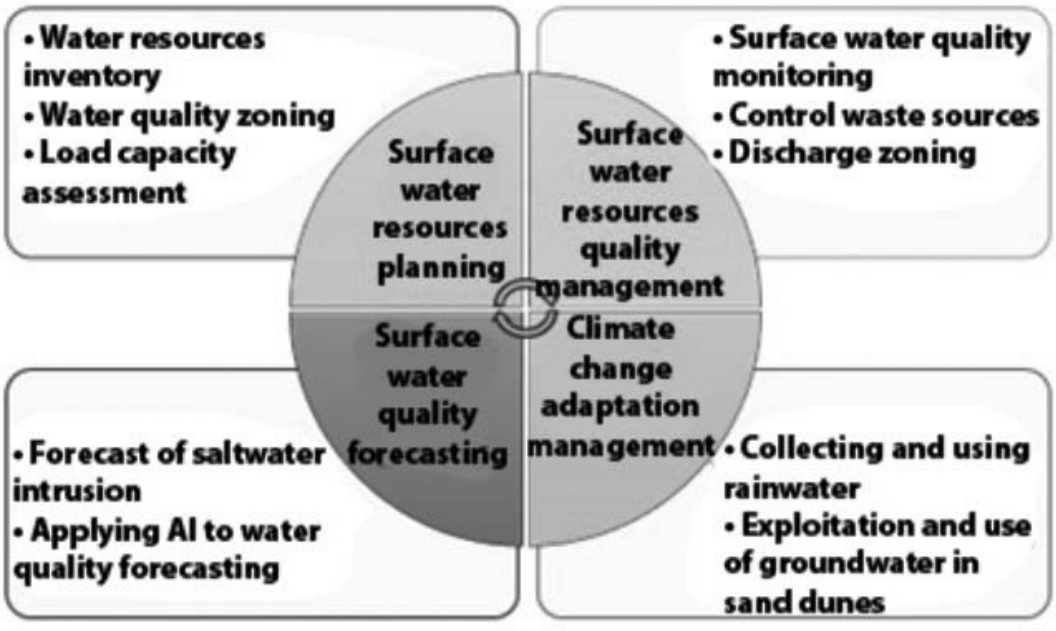

Figure 3. Management instruments and planning frameworks for supporting the closed-loop water management model in Ben Tre

reused for irrigation or to supply water for green spaces within production areas. This solution is especially appropriate during hot, dry seasons with limited rainfall and increased salinity. In the long term, the Provincial People's Committee should issue mandatory regulations on water recycling and reuse in industrial production. For example, requiring closed-loop systems for cooling water and reusing treated wastewater for on-site irrigation.

For rural and agricultural areas: Treated domestic wastewater can be reused for aquaculture activities combined with the cultivation of aquatic plants (such as duckweed, water spinach, or water mimosa, etc.).

3.2.2. Rainwater collection and usage

This solution has been and continues to be widely adopted around the world, as rainwater is a component of the natural water cycle, naturally clean and meeting standards for domestic water supply. Compared to high-density urban areas (such as Ho Chi Minh City), urban areas in Ben Tre have the advantage of more available space, making it easier to implement mandatory or recommended regulations for collecting rainwater from rooftops for purposes such as: household use (e.g., car washing, garden irrigation); supplying water for urban green spaces (parks, buffer zones); and contributing to the microclimate and landscape of broader urban areas.

On the other hand, rural areas affected by acid sulfate soils and limited water supply networks can benefit from rainwater as an alternative source during the dry season, when saltwater intrusion makes it difficult for rural water treatment and supply stations to operate effectively.

3.2.3. Integrated exploitation of surface water and groundwater

Surface water is the primary source for meeting water demand in Ben Tre Province. However, in recent years, the pressure on freshwater resources during the dry season has become the province's greatest challenge, particularly in coastal districts such as Ba Tri, Binh Dai, and Thanh Phu.

Thanks to the advantage of groundwater reserves formed during the late geological period (Holocene sediments) in coastal sand dune ecosystems, the exploitation and use of groundwater is entirely appropriate to meet domestic water needs in these coastal districts. The total exploitable groundwater reserves in the sand dune areas are estimated at 4,507 m^3/day in Binh Dai, 3,364 m^3/day in Ba Tri, and 3,169 m^3/day in Thanh Phu.

3.2.4. Strengthen and complete the water quality monitoring and management system

The water quality monitoring network is an inseparable component of the water source zoning and wastewater discharge zoning plans within the province. This element must be implemented in parallel to ensure effective surface water quality management, meeting the water use

demands of the province's three socio-economic zones and development corridors, as approved under Decision No. 1399/QĐ-TTg dated March 17, 2023, by the Prime Minister on the Planning forprovincial planning of Ben Tre Province for the period 2021–2030, with a vision to 2050.

3.3. Management plans and tools to support the implementation of the closed-loop water management model

To implement the closed-loop water management model, the research team infer:

Water source zoning and environmental zoning (strict protection zones, emission-restricted zones) must be carried out in accordance with Decision No. 1399/QD-TTg dated March 17, 2023, by the Prime Minister on the Planning of Ben Tre Province for the period 2021–2030, with a vision to 2050; and Decision No. 21/2017/QD-UBND by the Ben Tre Provincial People's Committee on environmental zoning for water bodies receiving wastewater within the province.

In addition, the Department of Agriculture and Environment must promptly implement the water resource inventory plan for the province, as stipulated in Decision No. 1381/QD-TTg dated August 4, 2021, by the Prime Minister, and guided by Official Dispatch No. 4464/BTNMT-TNN dated June 16, 2023, from the Department of Water Resources under the Ministry of Natural Resources and Environment (now the Ministry of Agriculture and Environment). This includes zoning for water quality, wastewater discharge, and assessing the carrying capacity of surface water bodies in accordance with Decision No. 21/2017/QD-UBND of the Ben Tre Provincial People's Committee.

At the same time, it is necessary to forecast saltwater intrusion and water quality changes due to environmental shifts and the impacts of climate change, as outlined in Plan No. 4646/KH-UBND of the Ben Tre Provincial People's Committee and Plan No. 4072/KH-STNMT of the Department of Natural Resources and Environment (now the Department of Agriculture and Environment) on managing and ensuring water security and freshwater supply in response to climate change for the period 2020–2030.

The closed-loop water management model is only implementable when implemented in parallel with water resource management plans and tools across Ben Tre Province (Figure 3).

4. CONCLUSION

Surface water resources are both a critical input and a limiting factor in the socio-economic development of the entire Mekong Delta region in general, and Ben Tre Province in particular. In Ben Tre, the pressure on both the quantity and quality of SWR consistently poses challenges for effective water resource management. As for Ben Tre's SWR is currently heavily contaminated by saltwater, the cost of technology to ensure the model works will be highly increasing. In addition, many communities and local stakeholders have limited understanding of water reuse, and water management responsibilities are often divided among multiple departments (agriculture, environment, construction, etc.). These challenges make up for the lack of coordination in addresing plans and informing roadmaps to the locals.

An integrated water resource management approach is a long-term solution that must be implemented with a forward-looking roadmap (beyond 2030, with a vision to 2050) to ensure the sustainable exploitation and use of water resources. Between 2025 and 2030, the implementation of a closed-loop water management model should be prioritized to align with Ben Tre's socio-economic development plans. The proposed model integrates rainwater harvesting, wastewater reuse, and discharge source control, while also applying artificial intelligence to forecast water quality and saltwater intrusion in the province. These components will be incorporated into a centralized water resource database management system, contributing to the enhancement and long-term preservation of water quality and reserves in Ben Tre■

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Preventing plastic pollution – from slogans to practical actions

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In an era of remarkable scientific and technological advancements, plastics, with their superior properties, were once considered a revolutionary invention, significantly contributing to socio-economic development. However, the rapid increase in plastic production and consumption, especially single-use plastic products, coupled with inadequate waste management systems, has transformed plastics from a convenient solution into a global "crisis." The international and Vietnamese communities' awareness of the harmful effects of plastic pollution has significantly shifted. Numerous commitments, initiatives, and policies have been introduced at global, regional, and national levels. Nevertheless, to address a systemic and complex issue like plastic pollution, general "slogans" or superficial movements are insufficient; more practical and specific action plans are required.

1. OVERVIEW OF THE PLASTICS INDUSTRY

1.1. The global plastics industry

Since the first synthetic polymers were discovered in the early 20th century, the plastics industry has experienced explosive growth. Global plastic production surged from about 2 million tons in 1950 to nearly 460 million tons in 2019, and it is projected to double by 2040 without strong interventions [1]. Common plastics like Polyethylene (PE), Polypropylene (PP), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), and Polystyrene (PS) have become indispensable materials in various sectors, from packaging (the largest share), construction, automotive, electronics, textiles, to healthcare and agriculture.

This robust growth is driven by several factors. Firstly, plastics possess outstanding properties: lightweight, durable, flexible, easy to mold, good electrical and thermal insulation, and, most importantly, relatively low production costs. The increasing consumer demand from a growing global population, along with urbanization trends and lifestyle changes favoring convenience, has created a massive market for plastic products, particularly single-use plastics. Plastics also play a crucial role in optimizing many industrial value chains, from reducing vehicle weight to save fuel to extending food preservation times.

The global plastic supply chain is a complex system, starting with the extraction of fossil fuels. According to a report by Stand.earth Research Group (SRG) and the Center for International Environmental Law (CIEL), a significant portion of petrochemical feedstocks for plastic production originates from fracking activities, especially in regions like the Permian Basin in the United States. The report indicates, "Over 25 of the world's largest household brands are driving fossil fuel expansion in Texas through their demand for plastic packaging." From these raw materials, giant petrochemical corporations produce plastic resins (polymers), which are then supplied to thousands of companies manufacturing finished plastic products worldwide, catering to the needs of major consumer brands [2].

The plastics industry makes substantial contributions to economic development by creating millions of direct and indirect jobs and significantly contributing to the GDP and export turnover of many countries. In 2022 alone, the global plastic value chain generated an estimated revenue of USD 1.7 trillion and created 6.3 million jobs [3].

However, the development of the plastics industry also reveals many systematic limitations: (i) heavy reliance on non-renewable fossil fuels (oil and gas account for about 99% of raw materials for plastic production [4]), depleting resources and contributing to the climate crisis through greenhouse gas emissions throughout the plastic lifecycle, from raw material extraction, production, to disposal. (ii) The dominant economic model in the plastics industry is still linear: extract – produce – consume – dispose. This model generates a large amount of waste and fails to utilize the value of materials after use, leading to resource waste and an increased burden on the environment. (iii) The responsibility of manufacturers for plastic products throughout their lifecycle, especially in the post-consumer phase, is often lacking or insufficient. This results in the costs of managing and treating plastic waste being typically shifted to society and local authorities, instead of being internalized into the product price.

1.2. Global plastic waste management status

The world is facing a colossal and ever-increasing volume of plastic waste. Between 1950 and 2017, the world generated approximately 6.9 billion tons of primary plastic waste, with an estimated 19-23 million tons leaking into aquatic ecosystems, from ponds, lakes, and rivers to the oceans [5]. Developing countries and emerging economies in Asia and Africa are often hotspots for plastic pollution due to rapid urbanization, increased consumption, and inadequate waste management systems. Global plastic waste management remains largely deficient, with estimates suggesting that only about 9% of all plastic waste ever produced has been recycled, 12% incinerated, and the vast majority (79%) accumulated in landfills or directly discharged into the natural environment [6].

From a socio-economic perspective, the tourism industry is severely affected as beaches and natural landscapes become polluted by plastic waste, reducing destination attractiveness and revenue. The fisheries sector also suffers losses due to declining resources (marine life ingesting plastics or getting entangled in plastic nets) and the risk of seafood contamination with microplastics, eroding consumer confidence. The costs of cleaning up polluted areas, treating plastic waste, and restoring the environment are enormous, burdening state budgets and communities. UNEP estimated the global economic cost of marine plastic pollution to sectors like tourism, fisheries, and aquaculture to be around USD 6-19 billion in 2018, with a forecast of up to USD 100 billion by 2040 [7]. Socially, plastic pollution directly impacts public health, especially in poor, vulnerable communities living near open dumpsites or unsanitary waste treatment areas. This situation also exacerbates social inequality, as the burden of pollution often falls heaviest on the most disadvantaged. Furthermore, the livelihoods of millions of informal workers in the waste collection and trading sector are affected by the volatility of the plastic scrap market and unsafe working conditions.

2. GLOBAL CONCERN OVER PLASTIC POLLUTION

2.1. Cooperative mechanisms to address plastic pollution: from awareness to action commitments

In recent decades, plastic pollution has transformed from a local environmental issue into a global crisis, attracting increasing international attention. At the 5.2 session of the United Nations Environment Assembly (UNEA) in March 2022, a historic resolution was adopted to initiate negotiations for an international legally binding agreement to end plastic pollution (UNEA Resolution 5/14) [8]. The goal of this treaty is to address the entire lifecycle of plastics, from product design, production, and consumption to waste management, to prevent plastic pollution in the environment, especially marine environments. Expectations for this treaty are high, but it also faces numerous challenges due to the diverse interests and capacities of nations.

Besides UNEP, organizations like the United Nations Development Programme (UNDP), the World Bank (WB), and the World Economic Forum (WEF) are actively implementing programs, projects, and initiatives to support member states. Regional intergovernmental organizations such as the European Union (EU) with its European Strategy for Plastics in a Circular Economy, and the Association of Southeast Asian Nations (ASEAN) with its ASEAN Regional Action Plan for Combating Marine Debris, have also made specific commitments and action roadmaps.

The private sector and international civil society organizations also play a pioneering role. The Ellen MacArthur Foundation's New Plastics Economy Global Commitment, involving hundreds of businesses, governments, and organizations, sets ambitious targets for eliminating problematic plastic packaging, innovating so that plastics can be reused, recycled, or composted, and circulating plastics in the economy. NGOs like WWF, Greenpeace, CIEL, and SRG continuously conduct advocacy campaigns, research, and monitoring, pressuring governments and businesses to take stronger actions.

2.2. Key approaches to addressing plastic pollution towards a Circular Economy (CE)

Transitioning from a linear economic model to a circular economy (CE) model is one of the most fundamental and widely recognized solutions to address the plastic pollution crisis. For the plastics industry, the core principles of CE include: (i) Designing out waste and pollution from the outset, meaning avoiding the use of harmful plastics and chemicals, and designing products for reusability, repairability, or recyclability; (ii) Keeping products and materials in use for as long as possible at their highest value, prioritizing solutions like reuse, repair, and refurbishment before considering recycling; (iii) Regenerating natural systems, ensuring that materials, after their end-of-life, can safely return to the cycle or biodegrade without harming the environment.

Technology and innovation are crucial drivers for realizing a CE for plastics. In recycling, besides improving mechanical recycling processes for better quality and efficiency, chemical recycling is gaining significant attention. Chemical recycling technologies

The world is facing a colossal and ever-increasing volume of plastic waste

like pyrolysis, gasification, and depolymerization can potentially process mixed plastics and contaminated plastics that are difficult for mechanical recycling and can produce feedstock of quality comparable to virgin plastics.

Sustainable alternative materials are also an important area of innovation. Bioplastics, including bio-based plastics and biodegradable plastics, are expected to reduce reliance on fossil fuels and address the long-term persistence of plastics in the environment. Additionally, optimizing and using traditional materials like paper, glass, and metal is also a significant direction.

Eco-design plays a pivotal role from the very beginning of a product's lifecycle. This includes minimizing material use, prioritizing mono-materials for easier recycling, eliminating toxic or hard-to-recycle components (like certain inks, labels, and adhesives), and designing products for easy disassembly, repair, or reuse.

New business models and policies promoting CE need to be developed. Business models such as Deposit-Return Schemes (DRS) for beverage containers, product-as-a-service models, sharing and collaborative consumption platforms, and systems for remarketing used products are increasingly being adopted.

Regarding economic policy instruments, Extended Producer Responsibility (EPR) is a crucial tool, requiring producers to bear financial and/or physical responsibility for managing their products post-consumption. Taxes or fees on hard-to-recycle plastics, single-use plastics, or plastic bags are also applied in many places to curb consumption. Conversely, subsidies and incentives for using recycled materials, environmentally friendly products, and green public procurement can create market drivers for CE. The development and enforcement of standards and technical regulations for mandatory recycled content in new products, for the quality of recycled plastic resins, and for the recyclability of packaging are also essential to promote the market and ensure quality.

Transitioning to a CE offers significant economic benefits. It helps create new markets for secondary raw materials, reduces dependence on imported or virgin raw materials, thereby saving production costs. CE also helps reduce waste treatment costs and minimizes economic damage from environmental pollution. More importantly, CE promotes innovation, creates new industries and jobs in sustainable design, repair, recycling, and related services, thereby enhancing the competitiveness of businesses and the economy. According to the World Economic Forum (WEF), the shift to a CE has the potential to add USD 4.5 trillion in additional production efficiency by 2030 [9]. Socially, CE contributes to minimizing the negative impacts of plastic pollution on public health and the living environment. It also fosters responsible consumption awareness, encourages community participation in environmental protection activities, and can create more sustainable livelihood opportunities for informal sector workers if properly integrated.

3. VIETNAM AND OTHER NATIONS IN PREVENTING PLASTIC POLLUTION

3.1. Vietnam's legal framework and strategic orientation

Recognizing the severity of the issue, the Vietnamese Government has issued and implemented numerous important policies and laws to strengthen the management and reduction of plastic waste pollution. The Law on Environmental Protection 2020 is considered a major step forward, with many new groundbreaking provisions demonstrating Vietnam's strong commitment to addressing environmental issues, including plastic pollution. Noteworthy are the regulations on municipal solid waste management towards enhancing source separation, promoting reduction, reuse, and recycling; regulations on Extended Producer Responsibility (EPR) for certain types of packaging (including plastic packaging) and products likely to cause pollution; and framework regulations to promote the development of a circular economy.

To concretize these orientations, the Government and the Prime Minister have issued many sub-law documents such as Decree No. 08/2022/ND-CP providing guidelines to several articles of the Law on Environmental Protection, and Decree No. 05/2025/ND-CP amending and supplementing several articles of Decree No. 08/2022/ND-CP, which include specific regulations on EPR. Important action plans and schemes have also been approved, such as the National Action Plan on Marine Plastic Debris Management by 2030 (Decision No. 1746/QD-TTg dated December 4, 2019), and the Scheme to Strengthen Plastic Waste Management in Vietnam (Decision No. 1316/QD-TTg dated July 22, 2021). Many national strategies and target programs on green growth and sustainable development also integrate content related to plastic waste reduction.

It is obvious that Vietnam's policy and legal framework for plastic waste management has made clear progress, demonstrating proactivity and strong political commitment in addressing this issue, while gradually aligning with international practices and standards such as EPR and CE.

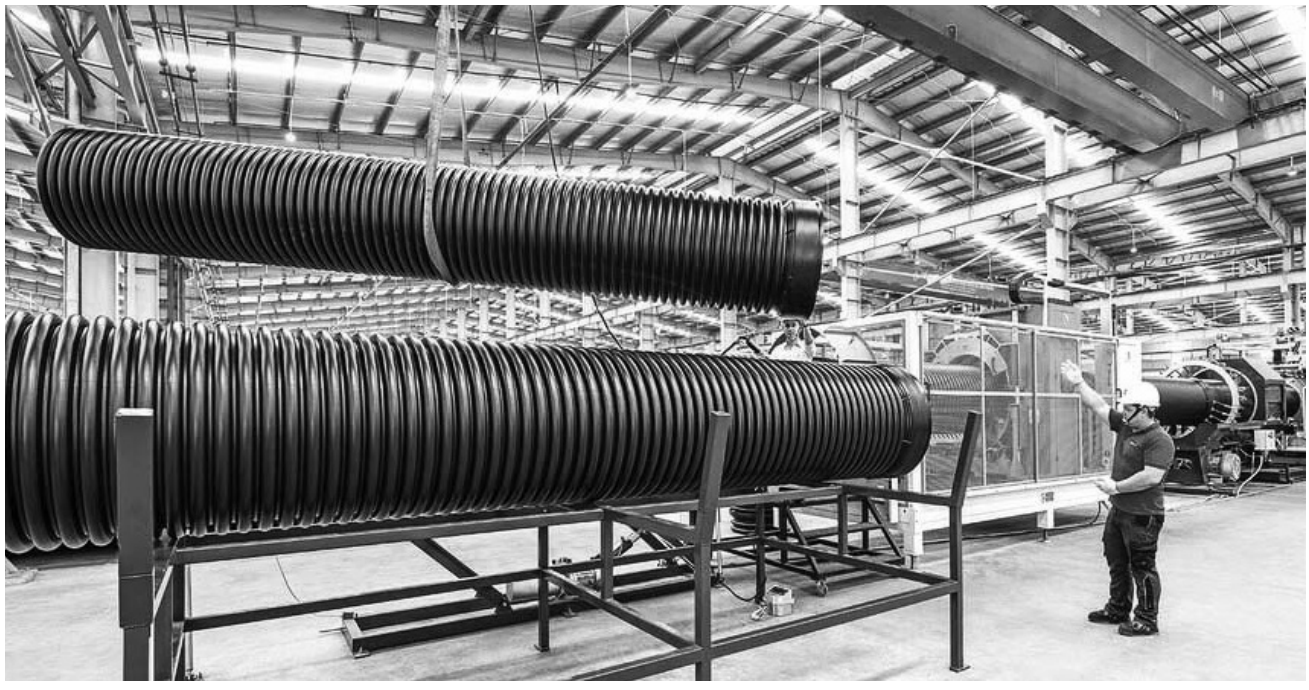
3.2. Vietnam's efforts in reducing plastic pollution

State management agencies from central to local levels have actively implemented national programs and schemes on plastic waste management. The Ministry of Natural Resources and Environment (now the Ministry of Agriculture and Environment) has chaired many activities to raise awareness, develop technical guidelines, and promote international cooperation. Many localities have issued their own action plans, piloting models for source separation, collection, and recycling of plastic waste. Initial results show a certain shift in awareness among a segment of the community and businesses; however, scaling up successful models and maintaining the sustainability of activities remain challenges.

The State has also made efforts to invest or call for socialized investment in infrastructure for collecting, sorting, and recycling plastic waste, although the scale and progress are still slow compared to demand. Inspection and examination activities regarding compliance with environmental protection laws related to the generation and management of plastic waste have also been strengthened. Many large-scale communication campaigns to raise public awareness about the harmful effects of plastic waste and the benefits of reduction, reuse, and recycling have been organized, attracting the participation of mass media and social organizations.

The Vietnamese business community, especially large enterprises and multinational corporations, is increasingly playing a more active role in reducing plastic pollution. Many businesses have pioneered research and application of solutions to change packaging design towards greater sustainability (using recycled materials, reducing packaging weight, eliminating hard-to-recycle components), using environmentally friendly alternative materials, and minimizing the use of plastics in products and production processes. Some businesses have boldly invested in modern recycling technology to treat plastic waste and develop new value-added products from recycled plastics. The emergence of alliances and voluntary initiatives such as the Packaging Recycling Organization Vietnam (PRO Vietnam), with the participation of leading consumer goods and packaging companies, or commitments to reduce plastic waste by the Vietnam Chamber of Commerce and Industry (VCCI), are positive signals. Corporate Social Responsibility (CSR) activities related to environmental protection, collection, and recycling of plastic waste are also becoming more common.

The participation of the residential community and social organizations plays an extremely important role. Many movements and campaigns to collect plastic waste and clean up the environment at beaches, rivers, and residential areas have been initiated and widely spread, attracting the participation of numerous volunteers, especially young people and students. Noteworthy is the formation and development of sustainable consumption models such as refill stores, alternative products to single-use plastics (bamboo/grass/stainless steel straws, cloth



Plastic pollution is one of the most pressing environmental challenges

bags, reusable food containers), and initiatives to reduce plastic bags at traditional markets. Non-governmental organizations (NGOs) and social organizations such as the Vietnam Women's Union and the Ho Chi Minh Communist Youth Union have been implementing many educational, communication, and behavior change advocacy programs, while also participating in community monitoring and policy advocacy activities.

Overall, promoting the reduction, reuse, and recycling of plastics is gradually creating new business models and niche markets for environmentally friendly and recycled products, thereby creating new job opportunities, especially in the collection, sorting, recycling, and green product manufacturing sectors. Businesses conscious of their environmental responsibilities and proactively applying sustainable solutions often build a better image and brand in the eyes of consumers and investors, thereby enhancing their competitiveness. Socially, these activities contribute to raising community awareness, improving the quality of the living environment in some areas, and promoting a more responsible lifestyle.

However, the implementation of activities still faces limitations, such as the small scale of many activities, especially from the community and social organizations, often being movement-based, lacking sustainability, and not yet creating a widespread impact nationwide. Financial, technical, and human resources for these activities are still very limited, often dependent on short-term funded projects. Coordination among stakeholders (Goverment - Business – Community) is sometimes not tight and synchronous. Changing the consumption behavior of a large part of the population is a long-term process, requiring perseverance and more creative and effective communication and education solutions. For businesses, transitioning to sustainable production and business also requires considerable time and investment resources.

3.3. Proposed solutions for reducing plastic pollution to ensure sustainable development in Vietnam

Perfecting institutions, policies, and enhancing enforcement effectiveness: Continue to review, amend, and supplement the system of legal documents related to plastic waste management towards synchronicity, clarity, feasibility, with clear roadmaps and effective enforcement sanctions. Issue more detailed regulations on EPR implementation, including mechanisms for managing and using the EPR fund transparently and effectively. Develop and implement effective economic instruments such as progressive environmental taxes on plastic products based on pollution levels or low recyclability; apply waste treatment fees based on generated volume to encourage source reduction. Concurrently, establish financial support and incentive mechanisms (taxes, credit, land) for businesses investing in cleaner production technologies, advanced recycling technologies, and the production of environmentally friendly products. Build and effectively operate a national database on

the generation, collection, transportation, treatment, and recycling of plastic waste to serve management, policymaking, and effectiveness evaluation.

Substantively promoting the development of a CE in the plastics industry: Encourage and further support research, development, transfer, and application of advanced recycling technologies (including chemical recycling if environmental standards and economic efficiency are ensured) and technologies for producing sustainable alternative materials. Develop markets for recycled and sustainable products through preferential policies in green public procurement, reputable eco-labeling programs, and support for supply-demand connections between recycled product manufacturers and businesses needing recycled materials. Support startups and innovative enterprises in this field.

Strengthening communication, education, raising awareness, and comprehensively changing behavior: Develop and implement long-term, systematic communication and education strategies with clear messages, engaging content, and diverse formats suitable for specific target groups (students, households, small traders, businesses, managers). Integrate educational content on environmental protection, sustainable consumption, the harmful effects of plastic pollution, and the benefits of CE into the formal education curriculum at all levels. Maximize the role of mass media and social media platforms in spreading positive messages, sharing knowledge, skills, and good examples in reducing plastic waste. Build and replicate programs and campaigns to encourage and honor individuals, groups, and businesses with practical initiatives and actions in reducing plastic pollution.

Enhancing international cooperation and resource mobilization: Vietnam needs to continue to proactively and actively participate in global and regional initiatives and commitments to reduce plastic pollution, especially in the negotiation and implementation of the International Agreement on Plastic Pollution. Fully implement committed national responsibilities. Maximize financial, technical, technological, and experiential support from international organizations, developed countries, and capable private partners. Promote scientific research cooperation, information sharing, and technology transfer in the field of plastic waste management and recycling. Effectively mobilize resources from society, including domestic and foreign private sectors, for investment projects in infrastructure and technology for treating and recycling plastics.

4. CONCLUSION

Moving from general "slogans" to "practical actions" in preventing and reducing plastic pollution is an urgent requirement and an inevitable path to ensure sustainable development. This is not merely an environmental protection responsibility but also an opportunity for us to restructure the economy towards a greener, more circular model, creating new economic values, jobs, and improving people's quality of life. For a green, clean, beautiful, and sustainably developed Vietnam, for the health of ourselves and future generations, let every individual and organization join hands, unite, and turn awareness and commitments into concrete, practical actions starting today to prevent and repel the plastic pollution disaster■

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THE 2025 UNITED NATIONS OCEAN CONFERENCE:

Accelerating action and mobilizing all actors to conserve andsustainably use the ocean

The third United Nations Ocean Conference (UNOC3) was held in Nice, France, from June 9th to 13th, 2025. Co-hosted by France and Costa Rica, the conference aimed to "accelerate action and mobilize all actors to conserve and sustainably use the ocean". It focused on supporting the implementation of Sustainable Development Goal 14 (SDG 14) related to marine life with three main priorities, to produce an ambitious Nice Ocean Action Plan: Working towards completion of multilateral processes linked to the ocean; Mobilizing finance resources for the SDG14 and supporting the development of a sustainable blue economy; strengthen and better disseminate knowledge linked to marine sciences to enhance policy-making.

Prime Minister Pham Minh Chinh delivered a keynote speech at the 2nd plenary session of the 3rd United Nations Ocean Conference in Nice, France, on June 9th

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The Conference involved all relevant stakeholders, bringing together Governments, the United Nations system, intergovernmental organizations, international financial institutions, other interested international bodies, non-governmental organizations, civil society organizations, academic institutions, the scientific community, the private sector, philanthropic organizations, indigenous peoples and local communities and other actors to assess challenges and opportunities relating to, as well as actions taken towards, the implementation of Goal 14.

This year's agenda at UN Ocean Conference will cover a range of topics related to ocean action from cooperation to sustainable fisheries to preventing and reducing marine pollution.

SOME OF THE KEY ISSUES TO WATCH

Implementing the high seas treaty and protecting biodiversity

The High Seas are some of the most biologically diverse and globally unique areas essential to life on Earth. These areas are beyond national jurisdiction cover an area equivalent to 50% of the Earth's surface and 64% of the ocean. Countries are now working to ratify the High Seas Treaty (BBNJ Agreement) to protect these critical ecosystems, while addressing the impacts of human activity, like the global shipping industry, to help mitigate its impact on marine biodiversity.

The Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement) was adopted on 19th June 2023 by the Intergovernmental Conference on Marine Biodiversity of Areas

Delegates pose for a group photo at the event

Beyond National Jurisdiction convened under the auspices of the United Nations. The BBNJ Agreement became the third implementing agreement to the United Nations Convention on the Law of the Sea.

Under the overall objective of the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction, for the present and in the long-term, through effective implementation of the relevant provisions of the Convention and further international cooperation and coordination, the Agreement addresses four main issues: Marine genetic resources, including the fair and equitable sharing of benefits; Measures such as area-based management tools, including marine protected areas; Environmental impact assessments; and Capacity-building and the transfer of marine technology. The Agreement also addressed a number of "cross-cutting issues", establishes a funding mechanism and sets up institutional arrangements, including a Conference of the Parties and various subsidiary bodies, a Clearing-House Mechanism and a secretariat. The Agreement is open for signature by all States and regional economic integration organizations from 20th September 2023 to 20th September 2025, and will enter into force 120 days after the date of deposit of the sixtieth instrument of ratification, approval, acceptance or accession.

Reducing emissions from the shipping industry

The shipping sector has a central role to play in enhancing ocean health, tackling climate change, halting biodiversity loss, strengthening resilience, and advancing global equity. More than 80% of global trade is transported by sea, and the global shipping industry is responsible for 3% of all global greenhouse gas emissions making green shipping a vital component of the global effort to protect the ocean from pollution and the impacts of climate change. Discover the innovative technologies and transformative approaches shaping the future of sustainable shipping.

Combating ocean acidification

Ocean acidification refers to a reduction in the pH of the ocean, which occurs when the ocean absorbs carbon dioxide (CO_2) from the atmosphere. Ocean acidification is exacerbated by pollution and climate change and directly threatens marine biodiversity and by extension, all those who rely on life below water for their food, livelihood, and cultural traditions. Reducing emissions is essential for combating ocean acidification, while regional science helps us find the best local response strategies.

The ocean and climate are intrinsically linked. Members of the International Alliance to Combat Ocean Acidification (OA Alliance) are leading discussions across climate and ocean policy platforms, ensuring that commitments, policies and communications accurately reflect their interdependence. Global problems like ocean acidification have local impacts and require unique actions. Through the development of Ocean Acidification Action Plans, OA Alliance members are proactively responding to the impacts of ocean acidification and promoting solutions that advance knowledge into policy action. OA must become a cross cutting issue embedded across climate, ocean

and marine science priorities, opportunities, and actions. Advancing domestic OA action will inform better decision making for achieving mitigation, adaptation, and resilience goals. By joining the OA Alliance and endorsing the Call to Action, members commit to creating a unique OA Action Plan. An OA Action Plan encompasses the actions that OA Alliance members will take (or are taking) to better understand OA in their region and accelerate OA mitigation, adaptation, and resilience nearshore.

OA Action Plan help governments: take inventory; prioritize needs and make recommendations; and align policies and investments in the face of climate-ocean change. This is especially important for achieving climate resilient fisheries and aquaculture, climate smart conservation, coastal resilience and habitat restoration, effective upgrades of infrastructure, and evaluation of marine carbon dioxide removal strategies.

OA Action Plans call forth renewed ambition to realize mitigation and adaptation targets in place across UNFCCC and deliver on Sustainable Development Goal 14.3, "to minimize and address ocean acidification." Additionally, OA Action Plans help prioritize science, policy, and funding needs across the UN SDG 14 and the UN Decade of Ocean Science for Sustainability.

Science for management action and effective policies

Science is essential to safeguarding the health of the ocean, and is fundamental to effective policies that drive climate action forward. In the lead up to the 2025 UN Ocean Conference, the One Ocean Science Congress will convene leading scientists, policymakers, and thought leaders around the world to explore how science can guide meaningful action and shape a sustainable future for the ocean. Science forms the core of our understanding of the rapidly unfolding climate crisis, as well as the foundation upon which the world can and must build solutions.

The ocean is fundamental to life on our planet and to our future. The ocean is an important source of the planet's biodiversity and plays a vital role in the climate system and water cycle. The ocean provides a range of ecosystem services, supplies us with oxygen to breathe, contributes to food security, nutrition and decent jobs and livelihoods, acts as a sink and reservoir of greenhouse gases and protects biodiversity, provides a means for maritime transportation, including for global trade, forms an important part of our natural and cultural heritage and plays an essential role in sustainable development, a sustainable ocean-based economy and poverty eradication.

PM Pham Minh Chinh (right) and Deputy PM and Minister of Foreign Affairs Bui Thanh Son at the opening session of the third UN Ocean Conference in Nice, France

VIETNAM ATTENDS UNITED NATIONS OCEAN CONFERENCE 2025

Vietnamese Prime Minister Pham Minh Chinh joined other world leaders at the opening ceremony of the third United Nations Ocean Conference (UNOC 3) in Nice, France, on June 9th morning under the theme Scaling up Ocean Action Based on Science and Innovation for the Implementation of Goal 14: Stocktaking, Partnerships and Solutions. The conference seeked to address marine and ocean challenges through finance and science & technology; and accelerate the ratification of the 2023 High Seas Treaty, which requires 60 ratifications to take effect by the deadline of September 20th, 2025. So far, only 32 countries ratified the document.

It aimed to end harmful subsidies to the global fisheries industry, which is considered a main cause of resource depletion. It is also expected to promote innovative ocean finance solutions, such as blue bonds and green loans to close the funding gap for marine conservation, one of the least-funded SDGs.

On the first day, the Prime Minister of Vietnam scheduled to deliver an important speech at the plenary session. He also co-chaired a summit on delta regions alongside the President of Iraq, and witnessed the official handover of Vietnam's

ratification document for the High Seas Treaty. The overarching theme of the Conference was "Accelerating action and mobilizing all actors to conserve and sustainably use the ocean". The Conference aimed to support further and urgent action to conserve and sustainably use the oceans, seas and marine resources for sustainable development and identify further ways and means to support the implementation of SDG 14. It built on existing instruments to form successful partnerships towards the swift conclusion and effective implementation of ongoing processes that contribute to the conservation and sustainable use of the ocean.

The Plenary Session 4 aimed to mobilize large-scale financial resources to restore ocean health and accelerated the transition to a sustainable, regenerative blue economy. Representatives from Norway, Chile, Germany and others pledged to mobilize both public and private investment for this goal, laying the groundwork for a future that connects human progress with environmental preservation.

The Prime Minister Pham Minh Chinh stressed that the ocean is not only a source of resources but also the origin of life and a vital connection between people and nature across all countries. For Vietnam, its more than 3,000 kilometers of coastline is not just a geographic reality, it is part of the nation's cultural identity and spirit. Developing the marine economy in a sustainable and effective way is a strategic choice and an essential requirement for Vietnam to chart its future and realize its vision of becoming a strong maritime nation and a high-income country by 2045. PM Chinh noted that while oceans cover 70% of the earth's surface, sustainable use and conservation receive the lowest level of investment among the UN's 17 Sustainable Development Goals. He called this a paradox and a serious warning. Now more than ever, he said, countries must work together through inclusive, comprehensive and global cooperation.

Advocating fairness, equality, inclusion and sustainability, he outlined the following proposals: Step up investment in marine science research and applications; promote technology transfer, joint research and experience sharing; and build a comprehensive ocean data system. Increase resource mobilization and ensure efficient, sustainable investment in the blue economy. Let governments take the lead, businesses drive innovation, and people join hands. International organizations should play a catalytic role, and developed countries should offer support to shape a green ocean finance ecosystem. Vietnam is ready to pilot this model. Enhance connectivity across continents, regions, and nations, and strengthen global ocean governance. The United Nations should take a central role, international law should serve as the foundation, and cooperation should be the key driver.

To build blue growth hubs and link key economic centers, PM Chinh said Vietnam is ready to participate and make positive contributions to the development of this network in the East Sea, a strategic sea area of the world. Although countries differ in political systems, development levels and cultural traditions, we share a common mission-to preserve the ocean as a vital space for life and sustainable development for today and for future generations. As a maritime nation, Vietnam pledges to be a reliable partner in global ocean protection. We pledge to join efforts in leading green and sustainable marine cooperation, and we stand ready to contribute to fair and sustainable blue finance initiatives.

VIETNAM AFFIRMS COMMITMENT TO GLOBAL OCEAN PROTECTION EFFORTS

Within France's third United Nations Ocean Conference (UNOC-3) framework, Vietnam was among the first countries to approve the Agreement on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (also known as the High Seas Treaty). At UNOC-3, Prime Minister Pham Minh Chinh announced that Vietnam had registered 15 voluntary ocean and marine governance commitments.

Prime Minister Pham Minh Chinh and the high-level Vietnamese delegation's participation in significant activities related to the High Seas Treaty demonstrates the Vietnamese Government's determination and concrete actions in the global effort to build a peaceful, prosperous, and sustainably developed ocean.

The High Seas Treaty is a historic milestone in the international community's efforts to protect the marine environment within the context of implementing the 2030 Agenda, especially Sustainable Development Goal 14 on the conservation and sustainable use of oceans, seas, and marine resources. This is the third Agreement negotiated and signed under the framework of the 1982 United Nations Convention on the Law of the Sea. The treaty takes effect 120 days after 60 countries have deposited their instruments of ratification or approval.

On June 9th, at the UNOC-3 plenary session, Prime Minister Pham Minh Chinh delivered a keynote

address representing the 10 ASEAN countries and shared Vietnam's perspectives on the conservation and sustainable use of oceans, seas, and marine resources. In his remarks, Prime Minister Chinh shared four priority orientations of ASEAN countries, including safeguarding the seas and oceans as spaces of peace, cooperation, development, and shared responsibility; promoting the integration of a consistent global approach and regional efforts in ocean and marine governance; recognizing seas and oceans as a core driver of prosperous development; and calling for accelerated global ocean governance based on cooperation instead of competition to expedite the implementation of SDG 14.

Prime Minister Chinh also emphasized the need to focus resources on three areas. First, investment in research, development, and application of marine science should be increased, including technology transfer, research cooperation, experience sharing, and building a global ocean data system. Second, boosting mobilization and efficient use of resources for sustainable blue economic development, with the spirit of "The State leads - Enterprises pioneer - People accompany - International organizations facilitate and support," creating a blue ocean finance ecosystem in which Vietnam is ready to pioneer a pilot model. Third, intercontinental, interregional, and international connectivity and global blue ocean governance should be strengthened under the "UN-centered - International law-based - International cooperation-led" principle to form "blue growth hubs" that link global marine economic centers. Vietnam is ready to actively participate in and contribute to developing this network in the East Sea (South China Sea), a strategic maritime area worldwide.

Previously, Vietnam was listed among the world's top ocean plastic polluters. In response and to demonstrate its responsibility to humanity, Vietnam has launched initiatives to raise public awareness and encourage businesses to reduce their dependence on single-use plastics. In addition, Vietnam has implemented a strong legal framework to address marine protection, with specific strategies such as the National Environmental Protection Strategy for 2030 emphasizing pollution control and marine ecosystem conservation.

In his speech at the conference, the Prime Minister called on the international community to act faster, stronger, and more decisively and for nations, regions, and the world to join hands in the conservation and sustainable use of the blue ocean. He called for faster and more drastic actions with the collective efforts of nations, regions and the entire world to conserve and use blue ocean in a more sustainable manner. To achieve that, the Vietnamese leader suggested the need for a scientific approach that is inclusive, people-centered, and comprehensive. From that perspective, the Vietnamese PM put forward six key directions:

First, policy making should be rooted in scientific evidence combined with traditional knowledge. It is necessary to deepen our understanding of marine ecosystem to fully access economic, social and environmental impact and leverage indigenous knowledge. This would ensure harmony between marine economic development and conservation of marine biodiversity as well as preservation of people's lifestyles, cultural traditions, and identities.

Second, it is essential to promote science an technology, innovation and digital transformation as a new driver for sustainable marine economic development.

Third, the international community should utilize resources for developing the marine economy. The State plays a facilitating role, businesses take the lead, the people actively participate and benefit from this process, international partners and financial institutions provide support. Public-private partnerships should be actively promoted.

Fourth, an integrated cross sector approach to ocean and marine governance should be adopted.

Fifth, it is vital to foster inter-regional, cross-border and transcontinental connectivity, establishing a network of blue marine economic hubs.

Sixth, it is essential to uphold international solidarity and cooperation in conservation and sustainable development of the oceans and seas.

The United Nations should play a central coordinating role in initiatives and cooperation programs. International law should serve as a coordinated action among nations based on fairness, equality and mutual benefits.

With the consistent policy of being a friend, an active and responsible member of the international community, Vietnam has been working closely with partners to take comprehensive and strong actions at various levels to realize the goal of conserving and sustainably using the marine environment, noted the PM■

NHÂM HIỀN

Vietnam's marine economy - Opportunities and challenges in the new era

NGUYỄN ĐỨC TOÀN
Vietnam Agency of Seas and Islands

Vietnam, with a coastline of more than 3,260 km, an exclusive economic zone three times larger than its mainland area, and more than 3,000 large and small islands, has great potential for economic development along with abundant resources and a strategic position in regional and international maritime transport. In the context of the country entering an era of strong growth, with the goal of double-digit economic growth, the marine economy is identified as one of important pillars to realize this ambition. In particular, the merger of provinces, reducing from 65 coastal provinces to 34 provinces, of which 21/34 provinces have sea. Along with strong administrative reform, decentralization and delegation of power, it is opening up new opportunities and challenges for sustainable marine economic development.

1. OPPORTUNITIES FROM THE MERGER OF PROVINCES AND ADMINISTRATIVE REFORM

1.1. Legal framework on marine exploitation and use is increasingly improved

On 28th June 2024, the National Assembly passed Resolution No. 139/2024/QH15 on the National Marine Spatial Master Plan for the 2021-2030 period, with a vision to 2050. On 7 October 2024, the Government issued Decision No. 1117/QD-TTg on the approval of the Master Plan for Sustainable Exploitation and Use of Coastal Zone Resources for the 2021-2030 period, with a vision to 2050. Plans to implement the above Master Plan have been approved by the Government and the Prime Minister. The Master Plan has divided areas encouraged for economic development activities, areas prohibited from exploitation, areas restricted from exploitation, areas requiring special protection for national defence, security and conservation purposes. The Master Plan has also oriented to prioritize the development of marine economic sectors, identified 5 key tasks and 4 breakthroughs to implement its goals. This is an extremely important legal framework for sectors and coastal localities to orient and implement marine economic activities.

In addition, Decree No. 65/2025/ND-CP of the Government amending and supplementing a number of articles of Decree No. 40/2016/ND-CP and Decree No. 11/2021/ND-CP has fundamentally resolved shortcomings and limitations in the management and use of sea areas, especially provisions related to the order and procedures for assigning sea areas for offshore wind power development. On the other hand, Decree No. 58/2025/ND-CP dated 3 March 2025 details a number of articles of the Electricity Law on the development of renewable energy and new energy, which stipulates specific criteria for selecting qualified contractors to participate in offshore wind power development. These issued legal regulations, master plans and plans have provided a solid legal framework for sustainable marine resource management, creating a comprehensive legal corridor to promote the development of marine economic sectors.

1.2. Increase space and management efficiency

The merger of provinces, in which one of the important criteria is to maximize the number of coastal localities, is a strategic step to optimize the exploitation and use of the potential of the sea. After the merger, new provinces will be larger in scale, with more concentrated resources, creating favourable conditions for the development of large-scale marine economic projects such as deep-water ports, coastal industrial parks and offshore wind farms, connecting the mainland with the sea. Provinces that are not coastal such as Hung Yen, Hai Duong, Ha Nam, Dak Lak, Dak Nong, Lam Dong, Can Tho, Binh Duong, etc. will have the opportunity to access the sea, thereby promoting production and reducing logistics costs (Table 1).

According to Resolution No. 36-NQ/TW dated 22 October 2018 of the 8th Meeting of the 12th Party Central Committee on the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045, the marine economy is expected to contribute about 10% of the country's GDP by 2030 and streamlining the administrative apparatus will help reduce overlaps, increase the effectiveness of inter-regional coordination to help accelerate the completion of the above goals. The merger also helps reduce administrative barriers between localities, creating favourable conditions for marine economic

Table 1: Summary of some major benefits of expanding marine space after the merger of provinces

Benefits	Details	Specific examples
Logistics enhanced	21 coastal provinces, the rate is increased from 44% to 62%, improving the seaport network.	Create a system of connecting roads from mountainous areas to seaports to speed up the transportation of goods and reduce logistics costs.
Large port clusters formed	Create mega cities with a strong port system, increasing cargo handling capacity.	Ho Chi Minh City crosses Hai Phong, Can Tho to the sea.
Inland & coastal economies connected	Link mountainous areas with the sea, expanding markets and supplies.	Dak Lak with Phu Yen, Lam Dong with Binh Thuan.
Investment in marine economy focused	Prioritize fisheries, renewable energy, beach tourism, sustainable growth.	Quang Ninh - Hai Phong - Ninh Binh with the core area starting to develop is Hai Phong - Quang Ninh with the focal point being Lach Huyen international port, developing Quang Ninh into a national tourist center connecting internationally. Ho Chi Minh City is developing into a leading maritime economic center in Southeast Asia. Priority areas are international transit ports, shipbuilding, ocean transportation; product inspection, training services for the marine economy; international trade and financial services.
Effectiveness of marine space management increased	Reduce administrative barriers, implement unified management of marine resources.	Develop Van Don and Dinh Vu economic zones, international financial centers in Da Nang and Ho Chi Minh City.

value chains to be more closely linked, from the mainland to offshore islands.

1.3. Implement administrative reform and decentralization, delegation of power

Along with the merger of provinces, Vietnam is promoting administrative procedure reform, reducing at least 50% of administrative procedures. Decentralization and delegation of power to coastal local authorities helps local authorities improve their efficiency and effectiveness at all levels. Specifically:

Enhance the initiative and flexibility of coastal local authorities: (1) Make decisions quickly in accordance with local characteristics: The policy on decentralization and delegation of power allows coastal provinces (especially after the merger, 21/34 provinces have sea) to be autonomous in planning, approving projects and allocating resources. For example, provinces such as Quang Ninh, Hai Phong, or Binh Thuan can quickly issue policies to attract investment in seaports, offshore wind power, or eco-tourism without waiting for approval from the Central Government, minimizing administrative time and costs; (2) Take local advantages: Each coastal province has its own natural and economic characteristics (such as the potential for sea breezes in Binh Thuan, rich fishing grounds in Kien Giang, or strategic logistics location in Hai Phong). Delegation of power helps local authorities flexibly develop appropriate marine economic development strategies, such as developing deep-water ports in Cai Mep - Thi Vai or high-quality tourist areas in Phu Quoc.

Attract investment and develop key marine economic sectors: (1) Create a favourable business environment: Decentralization and delegation of power go hand in hand with administrative procedure reform, cutting at least 50% of the processing time for procedures related to investment, land and environment. This creates favourable conditions for domestic and foreign investors to participate in marine economic sectors such as renewable energy, logistics, tourism; (2) Encourage

innovation: Local authorities granted autonomy can pilot new marine economic models, such as coastal economic zones integrating green energy, circular aquaculture, or smart tourism. Provinces such as Khanh Hoa have deployed pilot models of high-tech marine farming, contributing to increased productivity and export value.

Strengthen the effectiveness of marine resource management and environmental protection: (1) Implement flexible marine resource management: Delegation of power allows local authorities to directly monitor and manage marine resources, such as fishing grounds, conservation areas and energy exploitation areas. Some provinces such as Quang Ngai and Phu Yen have applied the fisheries co-management model, in which fishing communities participate in protecting aquatic resources, helping reduce overexploitation and conserve ecosystems; (2) Implement Net Zero commitments: Coastal local authorities are empowered to develop specific action plans to reduce emissions, such as implementing offshore wind power projects, using circular technology in aquaculture and plastic waste management. Binh Thuan, with 200 GW of wind power potential, is working with international investors to build offshore wind farms, contributing to the goal of reducing emissions by 50% by 2030.

Promote regional connectivity and synchronous infrastructure development: (1) Implement more effective inter-regional coordination: After the merger of provinces, coastal areas are reorganized into larger economic zones, helping strengthen connectivity between previously landlocked localities that now become coastal localities such as Hai Duong, Hung Yen, Ha Nam, Kon Tum, Dak Lak, Lam Dong, etc. (2) Invest in strategic infrastructure: Delegation of power allows local authorities to mobilize capital and implement key infrastructure projects, such as seaports, coastal roads and wind farms.

2. OPPORTUNITIES FROM INTERNATIONAL INTEGRATION

Vietnam's deep integration and participation in Free Trade Agreements (FTAs) such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the Regional Comprehensive Economic Partnership (RCEP), the European Union - Vietnam Free Trade Agreement (EVFTA), and other international commitments bring many significant advantages for the development of the marine economy.

Promote seafood exports and increase added value: (1) Expand export markets: Free Trade Agreements such as EVFTA (with the EU) and CPTPP (including Japan, Canada, Australia) reduce or eliminate tariffs on Vietnamese seafood products (shrimp, pangasius, and tuna). For example, EVFTA has reduced shrimp import tariffs from 12-20% to 0%, helping Vietnam increase seafood exports to the EU, Vietnam's second largest market (reaching about 1.2 billion USD in 2024); (2) Meet international standards: FTAs require high standards of traceability, combating illegal, unreported, and unregulated (IUU) fishing and environmental protection, encouraging Vietnam to improve fisheries management. This helps build a sustainable Vietnamese seafood brand, increasing competitiveness in the global market.

Develop the maritime industry and logistics: (1) Strengthen the role of a regional logistics center: Vietnam's geostrategic position on international shipping routes, combined with FTAs such as RCEP (including 15 Asia-Pacific countries), helps Vietnam become a cargo transit center. Seaports such as Cai Mep - Thi Vai and Hai Phong have welcomed the world's largest container ships, with a total cargo throughput of more than 750 million tons by 2024; (2) Attract investment in seaport infrastructure: Trade agreements facilitate attracting FDI capital into seaport development and logistics services. Corporations such as DP World (a multinational logistics company headquartered in Dubai, United Arab Emirates) and PSA International (the world's largest port operator, headquartered in Singapore) are investing in deep-water ports in Vietnam, thanks to tax incentives from FTAs and administrative reform; (3) Reduce logistics costs: FTAs help optimize global supply chains, reduce transportation costs and customs clearance times. According to the Draft Strategy for Vietnam's Logistics Services Development, logistics costs in Vietnam (accounting for 16-20% of GDP) can be reduced to 10-12% thanks to integration and reform.

Develop high-quality beach tourism: (1) Attract international visitors: Trade agreements and international integration, along with visa exemption commitments within the ASEAN and bilateral frameworks, help Vietnam attract a large number of tourists from major markets such as the EU, Japan and South Korea. In 2024, beach tourism contributed about 70% of the country's total tourism revenue (estimated at 28 billion USD), with destinations such as Ha Long Bay, Phu Quoc, Da Nang; (2) Invest in tourism infrastructure: Investors from Japan, Singapore, and the EU are investing capital in high-quality resorts and eco-tourism in coastal provinces, thanks to

incentives from FTAs and policies on decentralization and delegation of power; (3) Promote national brands: International integration helps Vietnam promote the image of island destinations, such as Ly Son and Con Dao, through global tourism promotion programs.

Develop marine renewable energy: (1) Attract capital and technology: International trade agreements and commitments (COP26) create favourable conditions for Vietnam to cooperate with advanced countries such as Denmark, Norway, the US and Germany in developing offshore wind power; (2) Access international green funds: International commitments on Net Zero help Vietnam access concessional capital sources from the World Bank (WB), Asian Development Bank (ADB) and Green Climate Fund (GCF) to develop renewable energy projects; (3) Transfer technologies: FTAs facilitate the transfer of advanced technologies, such as large-capacity wind turbines (10-15 MW) and floating foundations, helping Vietnam effectively exploit deep-sea areas.

3. CHALLENGES IN MARINE ECONOMIC DEVELOPMENT

Environmental pollution and climate change: Despite its great potential, Vietnam's marine economy is facing many challenges. Marine pollution, especially plastic waste and waste from aquaculture, is putting great pressure on marine ecosystems. It is estimated that each year, shrimp farming discharges nearly 3 million tons of solid waste and tens of millions of cubic meters of wastewater, causing degradation of ecological areas such as coral reefs and mangrove forests. Climate change, with rising sea levels and saltwater intrusion, also threatens coastal communities and port infrastructure.

Shortage of high-quality human resources: High-quality human resources in marine sector remain a bottleneck. Marine scientific research and human resource training facilities are currently in small scale, lacking modern equipment and failing to meet the needs of developing high-tech industries such as renewable energy or marine biology. The phenomenon of "brain drain" has also caused Vietnam to lose many experts in the field of marine economy, requiring policies to attract talent and invest in education.

Asynchronous infrastructure: Although there is a seaport system with a throughput capacity of over 750 million tons/year, many seaports are small, unsynchronized and have not been properly invested. Some localities have built seaports but cannot operate them effectively due to unreasonable calculations, causing waste of resources. This requires a more comprehensive and synchronous planning to optimize marine economic infrastructure.

4. SOLUTIONS AND DIRECTIONS

To take advantage of opportunities and overcome challenges, Vietnam needs to synchronously deploy the following solutions:

Firstly, develop a blue marine economy: Shift from a "brown" to a "blue" marine economy model, prioritizing sectors such as renewable energy, eco-tourism, and sustainable aquaculture. For example, offshore wind farms need to be combined with coral reef and mangrove conservation programs to ensure ecological balance.

Secondly, invest in technology and human resources: Increase investment in marine scientific research, apply remote sensing, AI and IoT technologies in resource management and environmental monitoring. In addition, establish a high-quality marine human resource training center, with policies to attract international experts.

Thirdly, strengthen international cooperation: Cooperate with countries strong in wind power technology such as Denmark, Norway, and Japan to transfer renewable energy technology and marine management; Participate in global initiatives such as Sustainable Development Goal 14 - Life below Water (SDG 14) to protect the ocean and attract green capital.

Fourthly, implement institutional reform: Continue to reduce administrative procedures, increase decentralization and delegation of power to coastal local authorities, and build a transparent legal framework to attract investment in large-scale marine economic projects.

5. CONCLUSION

In the era of the Vietnamese people's rise, the marine economy is not only a driving force for growth but also a symbol of the aspiration to become a strong and rich maritime nation. With the merger of provinces, administrative reform and the double-digit growth target, Vietnam is facing a historic opportunity to position itself as the center of the marine economy of the region. However, to realize this ambition, close coordination between the Government, businesses and the community is needed, along with a strong commitment to environmental protection and sovereignty over the sea and islands. Vietnam's marine economy, if properly exploited, will be the key to taking the country further on the journey of prosperity and sustainability■

Key tasks for realizing breakthroughs in the National Marine Spatial Planning of Vietnam (2021–2030, Vision to 2050)

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The National Marine Spatial Planning (MSP) of Vietnam for the period 2021–2030, with a vision to 2050, has been developed for the first time in Vietnam. It was approved by the National Assembly during its 7th session (15th legislature) and promulgated through Resolution No. 139/2024/QH15 dated June 28th, 2024. The scope of the MSP encompasses coastal areas, islands, archipelagos, marine zones, and the airspace over Vietnam. It represents a framework-level, comprehensive, integrated, cross-sectoral, dynamic, and open plan, which guides and concretizes the Party's policies and the State's legal framework on the management, exploitation, and use of marine space. It particularly embodies the spirit of Resolution No. 36-NQ/TW dated October 22, 2018, issued at the 8th Plenary Meeting of the 12th Central Committee, concerning the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045. The MSP also serves as a concrete expression of the National Master Plan and aligns with the National Land Use Planning.

The MSP provides strategic directions for the development of marine economic sectors and islands especially for 12 major island districts, including the Paracel (Hoang Sa) and Spratly (Truong Sa) archipelagos. It outlines four major breakthroughs to be achieved by 2030: (i) Development of logistics infrastructure and services in conjunction with the shipbuilding and maritime transport industries; (ii) Sustainable, responsible, and creative development of marine and island tourism, linked with the creation of green and smart island cities; (iii) Promotion of a green, circular, low-carbon, and resilient fisheries economy, prioritizing offshore aquaculture and fishing, integrated with marine conservation and cultural preservation; (iv) Rapid and sustainable development of clean and green marine energy sources, with a focus on offshore wind power; ensuring national energy security and defense; and conducting comprehensive research and assessment of the potential of offshore oil, gas, mineral resources, and seabed construction materials.

The marine space in the MSP is initially divided into four distinct zoning categories: Prohibited zones for exploitation; Conditional exploitation zones; Special protection areas; Encouraged development zones. This classification aims to resolve conflicts among economic sectors and between conservation, defense, and development objectives.

To implement the MSP, the Government issued Resolution No. 37/NQ-CP on May 27, 2025, which outlines 26 prioritized tasks, programs, and projects to be carried out by 2030. The key priorities include:

1. Reviewing and amending the Law on Marine and Island Resources and Environment and related

The key objectives in the National Marine Spatial Planning help allocate and organize marine spaces efficiently, serving economic, environmental, and national security interests.

The 7th session of the 15th National Assembly did indeed pass Resolution No. 139/2024/QH15, focusing on National Marine Spatial Planning for the period of 2021-2030, with a vision extending to 2050

legislation to enhance consistency and improve the effectiveness of resource management and marine environmental protection.

2. Promoting research and the application of information technology, digital technologies, and artificial intelligence in the development of coastal, marine, and island infrastructure and emerging marine industries.

3. Rapid and sustainable development of a green, circular, low-carbon, and resilient fisheries economy, efficiently using resources in conjunction with conservation, cultural preservation, defense, security, diplomacy, and international cooperation.

4. Investigation, evaluation, and sustainable exploitation of renewable energy sources, with an immediate focus on developing offshore wind power.

To fulfill these mandates, the Ministry of Natural Resources and Environment (MONRE), within its authority, issued Decision No. 1713/QD-BNNMT on May 28, 2025. This Decision promulgates the MONRE Implementation Plan for Resolution No. 37/NQ-CP, aiming to: (i) Intensify the execution of Resolution No. 139/2024/QH15 and Government Resolution No. 37/NQ-CP; (ii) Define a roadmap and assign responsibilities to MONRE departments to effectively implement the MSP.

One of the MONRE plan's top priorities to be pursued through 2030 is the survey, evaluation, and identification of priority areas for offshore wind development, based on the zones identified in the MSP. This aims to support the national target of achieving 6,000 MW of offshore wind capacity by 2030, in accordance with the National Power Development Plan approved by the Prime Minister in Decision No. 262/QD-TTg dated April 1st, 2024.

Additionally, to realize the goals outlined in Resolution No. 57-NQ/TW dated December 22, 2024, by the Politburo - regarding breakthroughs in science, technology, innovation, and digital transformation in the marine and island domains toward 2045 the MSP implementation will focus on: (i) Building and completing a technical system to support state management activities in sea area allocation and use; monitoring exploitation and use of marine and island resources and the environment; (ii) Researching and applying IT, digital technologies, and artificial intelligence in the development of marine infrastructure and emerging marine industries.

Through these strategic initiatives and implementation efforts, the MSP will help rationally allocate and organize marine space for economic, environmental, and national security interests, paving the way for a sustainable, prosperous marine economy in Vietnam■

DECREE NO. 65/2025/ND-CP: Some new points in provisions on assignment of sea areas to organizations, individuals for exploitation and use of marine resources

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On 12th March 2025, the Government issued Decree No. 65/2025/ND-CP amending and supplementing a number of articles of Decree No. 40/2016/ND-CP dated 15th May 2016 of the Government detailing the implementation of a number of articles of the Law on Marine and Island Resources and Environment and Decree No. 11/2021/ND-CP dated 10th February 2021 of the Government stipulating assignment of certain sea areas to organizations, individuals for exploitation and use of marine resources. In this Decree, many new points in provisions on assignment of sea areas to organizations, individuals for exploitation and use of marine resources have resolved difficulties and obstacles in management of activities of exploitation and use of marine resources; resolved some bottlenecks in administrative procedures through cutting down intermediate steps in the process of implementing administrative procedures on assignment of sea areas. This article focuses on some prominent amendments and supplements in Decree No. 65/2025/ND-CP on assignment of sea areas to organizations, individuals for exploitation and use of marine resources.

Firstly, the scope of regulation of Decree No. 11/2021/ND-CP has undergone major changes. In addition to the scope of assigning sea areas to organizations, individuals for exploitation and use of marine resources for non-military purposes, Decree No. 65/2025/ND-CP has stipulated that the scope of regulation includes assigning sea areas for military purposes. This provision covers all activities of exploitation and use of marine resources. Also, Decree No. 65/2025/ND-CP has not regulated the assignment of sea areas for sea encroachment to comply with

The variety of marine resources

legislations on land. Activities of sea encroachment have been stipulated under the Land Law 2024 and its guiding documents.

Secondly, Decree No. 65/2025/ND-CP has specifically stipulated activities that do not require assignment of sea areas. This is a new point compared to Decree No. 11/2021/ND-CP and is consistent with reality. According to provisions of Decree No. 11/2021/ND-CP, all activities of exploitation and use of marine resources (except for activities of use of sea areas for defence and security purposes that are not subject to scope of regulation) must carry out assignment of sea areas, however, many activities are difficult to carry out this. Therefore, it is appropriate to stipulate some activities that do not require assignment of sea areas. Specifically, Decree No. 65/2025/ND-CP stipulates activities that do not require assignment of sea areas, and these activities do not require payment of fees for the use of sea areas, including: (i) Activities of exploitation of aquatic resources at sea; activities of protection and regeneration of aquatic resources; activities of preservation of the sea in accordance with provisions of legislations on fisheries, environmental protection, and biodiversity; (ii) Activities of remedy of direct consequences caused by natural disasters and environmental incidents at sea; activities of construction of works for natural disaster prevention and control invested by the State or invested by organizations, individuals using non-state budget capital for non-profit purposes in accordance with provisions of legislations on natural disaster prevention and control; (iii) Activities of scientific research conducted

by foreign organizations, individuals in Vietnam's sea areas which have been licensed by competent state agencies in accordance with provisions of Article 19 of the Law on Marine and Island Resources and Environment.

In addition, (iv) Activities of exploration of oil and gas; activities of dredging in seaport waters, fishing ports, storm shelters for fishing vessels and shipping lanes (except for activities of dredging combined with product recovery) in accordance with provisions of legislations; (v) Activities of scientific research, measurement, monitoring, exploration and survey at sea conducted by state agencies; (vi) Activities of scientific research, measurement, monitoring, exploration and survey at sea carried out by organizations, individuals according to tasks approved, ordered or assigned by competent state agencies using the state budget (except for the case of performing scientific and technological tasks serving aquaculture); (vii) Activities of the maritime sector serving national and public interests and maritime infrastructure invested by the state budget serving national and public interests for non-profit purposes; Activities of construction and installation of works serving national and public interests invested by the state or invested by organizations, individuals using non-state budget capital for non-profit purposes; activities of survey, installation, maintenance, repair and recover of telecommunication cables at sea; (viii) Activities of use sea areas for national defence and security purposes, including cases of using sea areas for dumping at sea.

Thirdly, the authority to assign sea areas has been strongly decentralized, especially to the provincial level. Decree No. 65/2025/ND-CP abolished the authority of the Prime Minister and decentralized this authority to the Ministry of Agriculture and Environment and People's Committees of coastal provinces; in addition, some authorities of the Ministry of Agriculture and Environment were also decentralized to Provincial People's Committees. Accordingly, compared to provisions of Decree No. 11/2021/ND-CP, the scope of authority decentralized and delegated to Provincial People's Committees is very strong, including: (i) Sea areas assigned to organizations, individuals for implementation of investment projects to exploit and use marine resources under the approval or investment policy decision authority of the National Assembly, the Government, and the Prime Minister within the 6-nautical mile sea area; (ii) Sea areas proposed by foreign investors and foreign-invested economic organizations to be assigned for implementation of investment projects to exploit and use marine resources within the 6-nautical mile sea area (except for sea areas for aquaculture, the authority of which has been stipulated in the Law on Fisheries, not yet decentralized, still under the authority of the Ministry of Agriculture and Environment); (iii) Sea areas outside the 6-nautical mile sea area and within the administrative management scope of the sea of the provincial People's Committee for projects using sea areas for which the People's Committee of coastal province decides to approve the investment policy, approves the investment policy, and grants mineral exploitation licenses.

Fourthly, regarding the order for processing administrative procedures for assignment of sea areas, there has been a major step forward in cutting out a number of procedures and intermediate steps. Decree No. 65/2025/ND-CP has abolished the procedure for handing over sea areas in the implementation. In addition, regarding the procedure for appraising application dossiers for assignment of sea areas, the provision on establishing an appraisal council has been abolished and the consultation with relevant agencies has been simplified. Specifically, the Decree stipulates that it is not necessary to carry out the consultation procedure for cases where Vietnamese organizations, individuals have been granted an aquaculture license by a competent state agency in accordance with provisions of legislations on fisheries. In other cases, in the process of considering and issuing documents permitting the exploitation and use of marine resources to organizations, individuals, competent state agencies have consulted with a number of agencies as prescribed (Ministry of National Defence, Ministry of Public Security, Ministry of Agriculture and Environment) on the location, boundaries, and coordinates of the sea area where the sea area is proposed to be assigned, and the written opinions of these agencies are sent with the dossier applying for the assignment of the sea area, it is not necessary to carry out the procedure of consulting with these agencies. The Decree also have specific provisions on processing dossiers in cases where the dossier does not contain enough information to decide on the assignment of sea areas, the dossier appraisal agency shall send a written request to the organization or individual to provide additional information and explain contents that need to be clarified. In addition, the Decree also clearly stipulates the time limit and responsibilities of relevant agencies in the appraisal of dossiers applying for the assignment of sea areas.

Fifthly, Decree No. 65/2025/ND-CP specifically stipulates the assignment of sea areas for conducting activities of scientific research, measurement, monitoring, exploration, and survey at sea to resolve the biggest difficulties and obstacles in Decree No. 11/2021/ND-CP. The Decree specifically stipulates cases where sea areas must be assigned, dossiers, order and procedures, rights and obligations of organizations, individuals assigned sea areas, including a number of notable differences compared to the assignment of sea areas to organizations, individuals for exploitation and use of marine resources. Specifically, the Decree stipulates that the maximum period for assigning sea areas for conducting activities of scientific research, measurement, monitoring, exploration, and survey at sea shall not exceed 3 years; the decision on assignment of sea areas for conducting activities of scientific research, measurement, monitoring, exploration, and survey at sea shall not be amended, supplemented, or extended; in case 2 or more organizations or individuals submit an application to conduct a type of activity of scientific research, measurement, monitoring, exploration, and survey in the same sea area, in addition to appraisal contents specified in this clause, the appraisal agency must evaluate and propose the selection of organizations or individuals to assign the sea area based on the prescribed factors.

Regarding the rights and obligations of organizations, individuals assigned sea areas to conduct activities of research, measurement, monitoring, exploration and survey at sea, in addition to the rights and obligations prescribed in general for organizations, individuals assigned sea areas for exploitation and use of marine resources, the Decree has stipulated a number of specific obligations: organizations, individuals are allowed to publish and transfer information and results directly related to activities of scientific research, measurement, monitoring, exploration and survey at sea to third parties after obtaining written consent from the competent state agency that assigned the sea area; No later than 60 days from the date of completion of activities of scientific research, measurement, monitoring, exploration, and survey at sea, organizations, individuals must submit a summary report of the results to the competent state agency that assigned the sea area; no later than 10 days from the date of approval by the competent state agency of the investment policy for the project using the sea area that has used the results of activities of scientific research, measurement, monitoring, exploration, and survey at sea, organizations, individuals must submit detailed results of activities of scientific research, measurement, monitoring, exploration, and survey at sea, including: Original documents and detailed reports of the project using the sea area must be submitted to the Vietnam Agency of Seas and Islands, Ministry of Agriculture and Environment; within no more than 30 days from the date of completion of activities of scientific research, measurement, monitoring, exploration, and survey at sea, except in cases of force majeure as prescribed by civil legislations, the dismantling of means and equipment used and installed in the sea area must be completed.

Sixthly, Decree No. 65/2025/ND-CP has amended and supplemented provisions on fees for using sea areas and determining fees for using sea areas to meet practical requirements. The Decree has supplemented specific provisions on determining fees for using sea areas for special cases such as extending the deadline for assigning sea areas; using sea areas before organizations, individuals are assigned sea areas, etc. In addition, the Decree has stipulated the collection of fees for using sea areas for cases where organizations, individuals use them for multiple purposes.

Seventhly, Decree No. 65/2025/ND-CP has stipulated a number of transitional provisions to resolve difficulties and obstacles in the process of implementing the assignment of sea areas. Specifically, the Decree has stipulated methods for determining the authority to assign sea areas in cases where the administrative management boundary at sea has not been approved or issued by a competent state agency; in cases where the boundary between coastal provinces and centrally-run cities has not been agreed upon; in cases where the investment project is located outside the 6-nautical mile sea area and the responsibility for administrative management at sea has not been determined. In addition, the Decree also stipulates that in cases where the average lowest sea level edge over many years of islands has not been determined and announced by competent authorities as prescribed, the lowest sea level edge at the time of land inventory approved by competent authorities as prescribed shall be used to determine the scope of sea areas and sea zones.

Thus, Decree No. 65/2025/ND-CP has made major, quite complete and comprehensive amendments and supplements from the scope of regulation, authority, order and procedures for assigning sea areas, to provisions on determining fees for using sea areas; transitional provisions. These provisions are consistent with reality, resolving difficulties and obstacles in the assignment and management of exploitation and use of sea areas■

Some results of implementing the sustainable marine economic development strategy of Vietnam to 2030, vision to 2045

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Oceans provide half of the oxygen in the Earth's atmosphere, absorb half of all global carbon emissions, regulate climate, mitigate the impacts of climate change (CC), determine weather patterns, stabilize coastlines, temperature and water cycles. Oceans account for 80% of the planet's biodiversity (BD) and make a major contribution to food security and livelihoods.

The importance of seas and islands for each country and territory with a coastline is increasingly evident. The 21st century is identified as the "Century of the Oceans," set against a backdrop of economic growth, population growth, and increased use of natural resources, especially non-renewable resources on land. As a coastal nation, Vietnam has a coastline of over 3,260 km, with territorial waters under sovereign rights, jurisdiction over 1 million km², with 2 archipelagoes, Hoang Sa and Truong Sa, and over 3,000 islands and other archipelagoes. Over 50% of Vietnam's population lives in 28 coastal provinces and cities, with great potential for marine economic development.

Resolution No. 36-NQ/TW dated October 22th, 2018, on the Strategy for Sustainable Marine Economic Development of Vietnam to 2030, with a vision to 2045 (referred to as the Sustainable Marine Economic Development Strategy of Vietnam), clearly demonstrates the viewpoint of sustainable marine economic development based on green growth, biodiversity conservation, marine ecosystems; ensuring harmony between economic and natural ecosystems, between conservation and development, between the interests of localities with and without the sea.

The Sustainable Marine Economic Development Strategy of Vietnam, promulgated in 2018, has been implemented for nearly 7 years. Right from its promulgation, this major Resolution with many new ideas has brought expectations to many localities and marine economic sectors for strong and sustainable development. After a period of implementation, the Resolution has achieved initial results.

1. ROLE OF THE MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

The Ministry of Agriculture and Rural Development, as the Standing Agency of the National Steering Committee for the implementation of the Sustainable Marine Economic Development Strategy of Vietnam, has promoted the function of integrated management of marine resources and environmental protection of seas and islands; advised and submitted to the Government for promulgation Resolution No. 26/NQ-CP dated March 5, 2020, on the issuance of the Government's Overall Plan and 5-Year Plan for the implementation of Resolution No. 36-NQ/TW. Accordingly, the objectives, requirements, specific tasks, and solutions to be implemented by 2025 and 2030 are clearly defined, accompanied by a list of 51 schemes, projects, and tasks assigned to ministries, sectors, and localities for implementation in each phase.

The Ministry advises the Government to submit to the National Assembly for the promulgation of the National Marine Spatial Planning [1]; submits to the Government for promulgation the Overall Plan for Sustainable Exploitation and Use of Coastal Resources [2] as an important legal tool in the sustainable development of the marine economy.

Promoting the construction and improvement of the institution for sustainable marine economic development [3], implementing the review and improvement of the system of policies and laws on the sea in the direction of sustainable development [4]. In addition, many decisions, guidelines, and plans of the State are promulgated to create a legal framework in the establishment and construction of national marine spatial planning. With the motto of actively strengthening and expanding foreign relations and international cooperation on the sea. The issuance of these documents has gradually removed obstacles, difficulties, and inadequacies, creating a suitable legal basis for the effective operation of marine economic development activities.

2. SOME RESULTS OF IMPLEMENTING THE SUSTAINABLE MARINE ECONOMIC DEVELOPMENT STRATEGY OF VIETNAM

2.1. Specific objectives to 2030

Marine economy: The GRDP proportion of 28 coastal provinces and cities contributing to the total national GRDP from 2018 to 2022 is about 49

Sustainable marine economic development based on green growth, biodiversity conservation, marine ecosystems

- 51%, not yet achieving the target according to the Resolution of 65-70% of the country's GDP.

Society: The Human Development Index (HDI) of 28 centrally-run provinces and cities with the sea compared to the whole country is at an average level, not yet achieving the target according to the Resolution of being higher than the national average.

Basic investigation of resources and marine environment: Organized additional investigation of 130,927 km² of offshore sea area at a scale of 1:500,000, increasing the total area of basic investigation at a scale of 1:500,000 to 375,688 km² (about 38%) of the area of Vietnamese waters; investigating and assessing in detail the reserves and water quality for the construction of water supply projects for 14 islands.

Management and protection of marine ecosystems, coastal and island areas: To date, the country has established 12 marine protected areas (MPAs) with a total area of 206,224.93 ha, of which 185,000 ha are marine areas. The system of MPAs continues to be studied for expansion to achieve the target of MPAs accounting for 6% of the natural area of the national sea area.

2.2. Marine and coastal economic development

Marine tourism and services: Over the past time, there has been a rapid development of infrastructure and modern, high-class technical facilities in coastal localities, especially in the provinces of Hai Phong - Quang Ninh, South Central Coast, Phu Quoc (Kien Giang).

Maritime economy: Many important achievements have been made, and transportation capacity has been increasingly improved. As of the end of 2022, the total number of Vietnamese seagoing ships is 1,477 ships with a total tonnage of 11.6 million tons. The total volume of goods transported by the Vietnamese seagoing fleet has grown strongly, reaching 128.7 million tons.

Total export turnover of seafood: Increased from USD 8.8 billion in 2018 to over USD 10.9 billion in 2022, exporting seafood to 160 countries and territories. The structure of the seafood industry has changed dramatically in the direction of increasing the proportion of high-value farmed products, especially exports.

Completed the acceptance and direct sale of electricity in 11/12 island districts, 82/85 island communes, contributing to improving people's lives, socio-economic development, ensuring national defense, security, and firmly maintaining sovereignty over seas and islands.

Economic zones, coastal urban areas: As of the end of 2022, coastal economic zones across the country have 553 foreign investment projects with a total registered investment capital of USD 54.36 billion; there are 1604 domestic investment projects with a total registered investment capital of VND 1,371,723.5 billion. The whole country has 600 coastal cities with a population of about 19 million people.

2.3. Organizing the implementation of breakthroughs in improving the Institution of Sustainable Marine Economic Development

The Government promulgated Resolution No. 48/NQ-CP dated April 3, 2023, on the Strategy for Sustainable Exploitation and Use of Resources, Protection of Marine Environment and Islands to 2030, with a vision to 2050. Accordingly, marine and island resources must be exploited rationally, used efficiently, and equitably to serve socio-economic

development associated with ensuring national defense, security, foreign affairs, and international cooperation; marine environmental pollution is prevented, controlled, and significantly reduced; marine, coastal, and island biodiversity is protected, maintained, and restored; the values of natural heritage and marine cultural heritage are preserved and promoted; the impact of natural disasters is minimized, proactively and effectively responding to climate change and sea level rise, towards the goal of making Vietnam a strong maritime nation, rich from the sea.

Regarding National Marine Spatial Planning; Master Plan for Sustainable Exploitation and Use of Coastal Resources: National Marine Spatial Planning is an important legal tool in the sustainable development of the marine economy. The formulation of National Marine Spatial Planning is a large, complex, multi-sectoral, multi-disciplinary task that has been implemented for the first time. The Ministry of Agriculture and Rural Development has drastically focused resources on completing and advising the Government to submit to the National Assembly for the promulgation of the National Marine Spatial Planning; submitting to the Government for the promulgation of the Overall Plan for Sustainable Exploitation and Use of Coastal Resources; Plan to implement the National Marine Spatial Planning with a vision to 2050. The purpose is to specify the views, objectives, key tasks, breakthroughs, orientations, solutions, and important national projects approved by the National Assembly in the National Marine Spatial Planning.

3. SOME DIFFICULTIES

Over the past time, the implementation of the Sustainable Marine Economic Development Strategy of Vietnam has achieved certain results, contributing to the sustainable development of the marine economy. However, it is still slow compared to the set plan, and the implementation process has faced many limitations and difficulties, specifically: (i) The apparatus and human resources for state management of the sea are still limited, not keeping up with the development of the marine economy; (ii) The mechanism and policies to attract investment, especially from the private sector, for the development of marine economic sectors are not attractive enough; (iii) Lack of financial resources to implement projects, tasks, and tasks for marine economic development, the focus is on investment in the key program of basic investigation of resources, marine environment, and islands.

4. PROPOSED SOLUTIONS FOR SUSTAINABLE MARINE ECONOMIC DEVELOPMENT

Firstly, continue to review, evaluate, and propose amendments, supplements, and new construction of the system of laws on seas and islands to fully and comprehensively implement the contents set out in the Sustainable Marine Economic Development Strategy of Vietnam. At the same time, establish a system of integrated and unified state management agencies on seas and islands from central to local levels to ensure modernity, synchronization, and meet the requirements of state management tasks on seas and islands, sustainable marine economic development.

Secondly, make synchronous investments in basic investigation, scientific research, technology, and training of marine human resources; form a Center for research and application of marine biotechnology, and exploitation of deep seabed.

Thirdly, strengthen coordination in organizing implementation on a national scale, inspecting and guiding the organization of implementation of projects and tasks mentioned in the Sustainable Marine Economic Development Strategy of Vietnam, in the programs and plans promulgated by ministries, sectors, and localities with the sea.

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1.On June 28, 2024, at the 7th session, the 15th National Assembly passed Resolution No. 139/2024/QH15 on the National Marine Spatial Planning for the period 2021-2030, with a vision to 2050.

2.On October 7, 2024, the Prime Minister issued Decision No. 1117/QD-TTg in 2024 approving the Overall Plan for Sustainable Exploitation and Use of Coastal Resources for the period 2021-2023, with a vision to 2050.

3. Directive No. 31/CT-TTg, dated November 24, 2021, of the Prime Minister, "On renewing and strengthening the organization of the Sustainable Marine Economic Development Strategy of Vietnam to 2030.

4. Decree No. 42/2024/ND-CP dated April 16, 2024, of the Government on marine reclamation activities; Decree No. 65/2025/ND-CP of the Government amending and supplementing Decree No. 40/2016/ND-CP dated May 15, 2016, of the Government detailing the implementation of a number of articles of the Law on Natural Resources and Environment of Seas and Islands; Decree No. 11/2021/ND-CP stipulates the assignment of certain sea areas to organizations and individuals for exploitation and use of marine resources.

Improving legislations on integrated management of marine and island resourcesand environmental protection in the new era

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Vietnam is a maritime country, with a coastline of more than 3,260 km and more than 3,000 islands, including the Hoang Sa (Paracel) and Truong Sa (Spratly) archipelagos. The marine economy is an important driving force and premise for socio-economic development, environmental protection, national defence, security, foreign affairs and international cooperation. Vietnam's coastal provinces and cities account for more than 50% of the country's population, most of whom work in marine-related sectors; the contribution of 28 coastal provinces and cities to the country's GDP has now exceeded 60%. In the current situation, after negative impacts of the COVID-19 pandemic and the general recession of major economies in the world, the coastal economy and marine economic sectors play an increasingly important role in restoring socio-economic activities and promoting Vietnam's economic growth.

1. REQUIREMENTS FOR INSTITUTIONAL BREAKTHROUGHS IN NATIONAL DEVELOPMENT IN THE NEW ERA

Institutional improvement is identified as one of three strategic breakthroughs to create a new momentum with strong spreading power, liberate all potentials, and effectively exploit resources for rapid and sustainable economic development. The focus of institutional breakthroughs is also clearly identified, in particular, the 13th National Party Congress identified the focus of institutional breakthroughs as institutions for development, emphasizing the priority of synchronous, high-quality improvement and good organization for implementation of the legal system, mechanisms, and policies, creating a favourable, healthy, and fair investment and business environment for all economic sectors, promoting innovation; mobilizing, managing, and effectively using all resources for development.

Fully aware of the position, role and importance of the marine economy, Vietnam has had many important guidelines and policies for sustainable development of the marine economy. The 12th Party Central Committee issued Resolution No. 36-NQ/TW dated 22 October 2018 on the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045. To institutionalize and concretize the Party's guidelines, the Government of Vietnam issued Resolution No. 26/NQ-CP dated 5 March 2020 on the Government's Overall Plan and 5-year Planto Implement Resolution No. 36-NQ/TW. On 24 November 2021, the Prime Minister issued Directive No. 31/CT-TTg on Renewing and Strengthening the Organization for Implementation of the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045.

Since the 1990s, the importance of the sea/ocean for national development has been recognized through specific policy instruments. In 2007, Resolution No. 09-NQ/TW on Vietnam's Marine Strategy to 2020 was issued with a focus on becoming a "strong maritime nation" through "exploiting all potentials from the sea". The Resolution's goal is that by 2020, the marine economy will contribute about 53 - 55% of GDP and 55 - 60% of the country's export turnover as well as supporting social development. The importance of sectors that make up the marine economy has been recognized and sectoral policies have become clearer, such as the Vietnam's Fisheries Development Strategy 2010; the Vietnam's Tourism Development Strategy 2010; the Vietnam's Transport Development Strategy 2010; some of these policies have been reinforced by Laws. Resolution No. 36-NQ/TW dated 22 October 2018 of the Party Central Committee on the Strategy for Sustainable Development of Vietnam's Marine Economy once again emphasizes the sea/ocean. The Resolution identifies targets to 2030 and a vision to 2045, including 5 main directions and 7 key solutions, as well as 3 "breakthrough" steps also identified in the Resolution. In particular, the first breakthrough step is identified to be: Improving the institution for sustainable development of the marine economy, prioritizing the improvement of the legal corridor, innovation, development of green growth model, environmental protection, enhancement of productivity, quality, international competitiveness

The marine economy is an important driving force and premise for socio-economic development, environmental protection

of marine economic sectors, sea and coastal areas; improving the mechanism for integrated and unified marine management; reviewing, adjusting, supplementing and establishing new master plans related to the sea, ensuring connectivity and synchronization between sectors and localities (inter-sectoral and spatial integration).

Thus, "Improving legislations on integrated management of marine and island resources and environmental protection for sustainable development of marine economy, meeting requirements in the new era" is an important, specific and urgent task, aiming to deeply institutionalize the Party's viewpoints and orientations stated in the document of the 13th National Party Congress, Resolution No. 36-NQ/TW on the Strategy for Sustainable Development of Vietnam's Marine Economy and political tasks of the Party Committee of the Ministry of Agriculture and Environment, the Party Committee of the Viet Nam Agency of Seas and Islands and especially to meet requirements of fundamental innovation in law-making and enforcement in accordance with Resolution No. 66-NQ/TW dated 30 April 2025 of the Politburo on Innovation in Law-Making and Enforcement to Meet Requirements of National Development in the New Ara. This is the guideline for us to review and promote the improvement of policies and legislations on sea and islands.

2. NECESSITY AND BASIS FOR IMPROVING LEGISLATIONS ON INTEGRATED MANAGEMENT OF MARINE AND ISLAND RESOURCES AND ENVIRONMENTAL PROTECTION

The Law on Marine and Island Resources and Environment 2015 was passed by the 13th National Assembly of the Socialist Republic of Vietnam at the 9th session on 25th June 2015, and took effect from 1st July 2016. The Law and documents guiding its implementation have formed an important legal document system, creating a corridor for integrated and unified state management of marine and island resources and environmental protection, contributing to creating positive changes in the awareness and actions of the whole society in effectively protecting, exploiting, maintaining functions and structures of marine, island and coastal ecosystems, gradually promoting sustainable development of the marine economy, protecting Vietnam's sovereignty, sovereign rights and national jurisdiction at sea, and ensuring national defence and security. Entering a new era, which is the era of the Fourth Industrial Revolution, of green growth, circular economy, digital economy; an era with increasingly severe non-traditional security challenges such as climate change, transboundary marine pollution (especially ocean plastic waste), the issue of conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction, and the rapidly increasing demand for exploitation and use of marine resources.

The country's practice of developing the marine economy and international integration has also undergone many changes. The implementation of arrangement and reorganization of administrative units at all levels and establishment of a two-level local government organization model are also major orientations for Vietnam to become a digital, stable and prosperous country, pioneering in testing new technologies and models; fundamentally and comprehensively innovating management and operation activities of the Government and local authorities and expanding the scope of marine space for sustainable development of the marine economy, strengthening ocean governance capacity for management levels.

In that context, the Law on Marine and Island Resources and Environment and its guiding documents for implementation, as well as legislations on marine resource management and use, have revealed a number of limitations and shortcomings, such as: Some provisions are not really flexible and constructive to liberate all resources for new marine economic models; there are also limitations, shortcomings, interferences, and

overlaps with a number of other specialized laws that have been recently issued or amended, causing difficulties in organizing implementation. Some provisions have not kept up with reality, financial mechanisms for marine environmental protection, as well as sanctions for violations are not deterrent enough, etc. Therefore, the study of comprehensive amendments to legislations on marine and island resources and environment in general and the Law on Marine and Island Resources and Environment in particular is an objective and urgent requirement, aiming to meet practical demands and, more importantly, to realize the spirit of "Constructive legislations for development, that liberate all resources and encourage innovation".

3. NEW ORIENTATIONS AND PRINCIPLES FOR AMENDING LEGISLATIONS ON INTEGRATED MANAGEMENT OF MARINE AND ISLAND RESOURCES AND ENVIRONMENTAL PROTECTION

Resolution No. 66-NQ/TW of the Politburo on Innovation in Law-Making and Enforcement marked a profound change in the concept of the role of legislations. If in the past legislations were mainly considered tools for regulating and managing society, it is now affirmed as the core foundation of the rule of law State, a lever to promote development, and a shift in thinking from "management" to "service". Legislations are not only tools of the State but also means to protect legitimate rights of people and businesses. The requirement that legislations must be "one step ahead" demonstrates a strategic vision and a deep awareness of the pioneering role of institutions in creating an environment for development.

The amendment of legislations on integrated management of marine and island resources and environmental protection needs to ensure core principles in accordance with Resolution No. 66-NQ/TW and the Party's major orientations on marine economic development.

Firstly, strongly innovate the thinking of law-making towards creation for development, liberation of resources, and encouragement of innovation for the marine economy: Legislations must be tools to guide and promote the marine economy towards sustainable development, green growth, improvement of the living standard of coastal people, and firmly protection of the marine and islands overeignty; Abandon the thinking of "if you can't manage it, then ban it"; Review and amend current legal provisions to remove barriers and facilitate legal investment and business activities at sea, especially for high-tech marine economic sectors, marine renewable energy, marine ecotourism, and sustainable aquaculture; Build legal sandboxes for new marine economic models and advanced, environmentally friendly marine resource exploitation technologies.

Secondly, implement integrated, ecosystem-based management: Strengthen the integrated, inter-sectoral, inter-regional management approach; protect and restore marine ecosystems as the center and foundation for sustainable development.

Thirdly, ensure transparency, publicity, accessibility and feasibility: Provisions must be clear, specific, ensure feasibility, applicability, and create favourable conditions for people and businesses to easily access and comply.

Fourthly, promote modernization, enhance digital transformation, apply science and technology, and artificial intelligence in law-making and enforcement: Integrate digital technology and artificial intelligence solutions into the management and monitoring of marine resources and environment; build a synchronous national database system on marine resources and environment, integrated with the legal information system; apply remote sensing technology and artificial intelligence (AI) in monitoring resource exploitation activities, detecting pollution, and forecasting marine environmental incidents.

Fifthly, proactively implement international integration: Ensure compatibility with international treaties of which Vietnam is a member, selectively absorb good experiences from the world.

Sixthly, create a breakthrough in organization for law enforcement, ensuring that legislations are implemented fairly, strictly, consistently, promptly, effectively and efficiently: Promote decentralization and delegation of power, clearly define the functions, tasks, authority and responsibilities of each level, organization and individual; build a close and effective inter-sectoral and inter-regional coordination mechanism in patrolling, controlling, detecting and handling violations; publicize and be transparent in law enforcement activities; study and apply sanctions that are sufficiently deterrent to serious violations of legislations on marine resources and environment.

In particular, ensure the comprehensive and direct leadership of the Party throughout the process from marine and island law-making to organizing for enforcement: Party committees at all levels must identify this as a key political task, regularly inspect and supervise the institutionalization of Party guidelines and the organization for law enforcement. Promote the

role of Party committees, secretaries and heads of units in the development of institutions and legislations.

4. KEY CONTENTS THAT NEED TO BE STUDIED, AMENDED AND SUPPLEMENTED

Based on those orientations and principles, some key contents that need to be focused for study, amendment and supplement include:

Firstly, supplement and improve provisions to effectively implement the management and use of national marine space and the Master Plan for Sustainable Exploitation and Use of Coastal Resources. Accordingly, it is necessary to ensure multi-sectoral, multi-objective, flexible integration with a long-term vision, creating space for new marine economic sectors, while protecting environmentally, national defence and security sensitive areas; clarifying the relationship with sectoral and provincial master plans.

Secondly, supplement and clarify provisions on management and protection of important marine ecosystems, marine and coastal biodiversity such as coral reefs, seagrass beds, mangrove forests, marine reserves; develop a mechanism for payment of marine ecosystem services, develop "ecosystem-based economy", etc.

Thirdly, specifically stipulate management and reduction of marine environmental pollution especially land-based, transboundary pollution, ocean plastic waste pollution; issues related to the marine environment due to maritime activities, handling of spills of oil and toxic chemicals at sea, as well as the handling of offshore structures and equipment after the expiration of their exploitation and use period.

Fourthly, develop economic instruments in managing marine resources and environment such as environmental protection fees for marine activities, sustainable marine development funds, and mechanisms for auctioning marine resource exploitation rights in a public and transparent manner.

Fifthly, encourage and create a legal corridor for activities of scientific research, development and application of advanced marine technology such as marine renewable energy, marine biotechnology, deep sea resource exploitation, and pollution treatment technology.

Sixthly, improve provisions to contribute to responding to climate change and sea level rise, preventing and responding to marine environmental incidents by strengthening inter-sectoral and inter-regional coordination mechanisms; enhancing the resilience and adaptation of natural and social systems in coastal areas; clarifying responsibilities of each ministry, sector and local authority in marine resource management, environmental protection and law enforcement.

Seventhly, supplement provisions to internalize a number of important international treaties to which Vietnam is a member, such as provisions of the International Convention on Civil Liability for Oil Pollution Damage 1992 (CLC1992), the International Convention on Civil Liability for Bunker Oil Pollution Damage 2001(BUNKER 2001) on compensation for oil pollution at sea; related issues on conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction in the Agreement on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement).

Eighthly, enhance the role, responsibility and participation mechanism of the community and businesses in the process of developing regulations and monitoring the exploitation and use of marine and island resources and environmental protection.

Obviously, the study, amendment and improvement of the system of policies and legislations on the sea and islands in general, and the Law on Marine and Island Resources and Environment in particular, is a specific and important step to successfully implement viewpoints and objectives of Resolution No. 36-NQ/TW dated 22 October 2018 on the Strategy for Sustainable Development of Vietnam's Marine Economy, Resolution No. 66-NQ/TW dated 30 April 2025 on Innovation in Law-Making and Enforcement to meet eequirements of national development in the New Ara. This is not only a responsibility but also an opportunity for us to create breakthroughs in building a strong maritime legal system, creating and promoting sustainable development of the maritime economy, protecting the environment, firmly protecting national marine sovereignty and interests, making our country truly a strong and rich maritime nation, building a strong and happy Vietnam■

REFERENCES

1. Resolution No. 36-NQ/TW dated 22 October 2018 of the 12th Party Central Committee on the Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a vision to 2045.

2. Resolution No. 66-NQ/TW dated 30 April 2025 of the Politburo on Innovation in Law-Making and Enforcement to Meet Requirements of National Development in the New Ara.

3. Law on Marine and Island Resources and Environment 2015.

4. Report No. 303/BC-BTNMT dated 31 December 2024 of the Ministry of Natural Resources and Environment on summary of the implementation of the Law on Marine and Island Resources and Environment.

DUMPING AT SEA: Current situation and solutions

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Dumping at sea is an indispensable part of marine and island environmental protection activities. Many types of waste, such as mud and sand dredged during port construction, channel maintenance, old and broken ships, etc. cannot be dumped on shore but must be dumped at sea. Therefore, dumping at sea has been permitted in legislations internationally and of many countries, including Vietnam.

1. REGULATIONS RELATING TO DUMPING AT SEA

1.1. International conventions on dumping at sea

The United Nations Convention on the Law of the Sea 1982, of which Vietnam is a member, stipulates rights and obligations of states in relation to the sea and oceans, including dumping at sea. Accordingly, this Convention defines "Dumping" as: (1) Any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea; (2) Any deliberate disposal of vessels, aircraft, platforms or other man-made structures at sea.

In addition, the issue of dumping is also specifically stipulated in the London Convention 1972 – The Global Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter; the London Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1996. In which, it is stipulated that dredged material is allowed to be dumped into the sea based on the fact that this is a material brought up from the seabed, so returning it to the sea is a very natural thing if this material does not contain toxic substances that can change the marine environment in a bad direction.

1.2. Legal regulations of Vietnam on dumping at sea

a) Law on marine and island resources and environment

Articles 57 to 63 of the Law on Marine and Island Resources and Environment stipulate dumping at sea, focusing on following contents: Requirements for dumping at sea; objects and substances permitted to be dumped at sea; Permit for dumping at sea; issuance, re-issuance, extension, amendment, supplement, permission to return, revocation of Permit for dumping at sea; rights and obligations of organizations and individuals granted Permit for dumping at sea; control of dumping activities at sea; dumping outside Vietnam's sea areascausing damage to Vietnam's marine and island resources and environment.

b) Decree No. 40/2016/ND-CP dated 15 May 2016 of the Government detailing the implementation of a number of articles of the Law on Marine and Island Resources and Environment; Decree No. 65/2025/ND-CP dated 12 March 2025 of the Government amending and supplementing a number of articles of Decree No. 40/2016/ND-CP and Decree No. 11/2021/ND-CP dated 10 February 2021 of the Government stipulating the assignment of certain sea areas to organizations and individuals for exploitation and use of marine resources

Articles 49 to 60 of the Decree No. 40/2016/ND-CP dated 15 May 2016 of the Government stipulate contents of issuance, re-issuance, extension, amendment, supplement, permission to return, revocationof Permit for dumping at sea; list of objects and substances permitted to be dumped at sea.

c) *Decree No. 57/2024/ND-CP* dated 20 May 2024 of the Government stipulating the management of dredging activities in seaport waters and inland waterway waters

Articles 4 to 7 of the Decree No. 57/2024/ND-CP stipulate principles of dredging and dumping; planning of dredged material receiving points; environmental protection during dredging and dumping at sea.

d) Decree No. 37/2022/ND-CP dated 6 June 2022 of the Government amending and supplementing a number of articles of Decrees on sanctioning of administrative violations in national defence, cryptography; management, protection of national borders; in the sea, islands and continental shelf of the Socialist Republic of Vietnam.

This Decree stipulates fines for groups of violations of provisions on dumping objects and substances in Vietnam's sea areas, specifically: Violations in implementing the Permit for dumping at sea; violations of other provisions on dumping objects and substances in Vietnam's sea areas; violations of dumping objects and substances in Vietnam's sea areas without a Permit for dumping at sea in Clauses 14, 15, 16, Article 3, Decree No. 37/2022/ND-CP with fines from VND5,000,000 to VND1,000,000,000.

e) *Circular No. 28/2019/TT-BTNMT* dated 31 December 2019 of the MONRE (now the MAE)

stipulating technical regulations for assessing dredged materials and determining dredged material dumping sites in Vietnam's seaareas; Circular No. 23/2022/TT-BTNMT dated 26 December 2022 of the MONRE amending and supplementing a number of articles of Circular No. 28/2019/TT-BTNMT

The MAE has stipulated contents and steps for assessing dredged materials for dumping; sampling dredged materials (quantity, sampling locations, analysis parameters, etc.); assessing the composition of dredged materials for dumping; contents and steps for determining dumping sites, proposing feasible areas, assessing in detail proposed areas, selecting and determining possible dumping locations, etc.

2. PRACTICE OF DUMPING ACTIVITIES AT SEA

2.1. Practice of dumping activities at sea in the world and in Vietnam

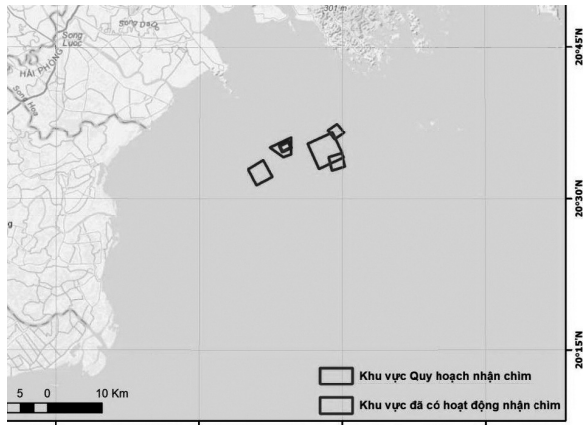
Dumping of dredged objects and substances at sea in the world as well as in Vietnam is still carried out regularly, serving the maintenance and dredging to ensure the operation of seaports and shipping routes. According to data from the International Maritime Organization (IMO) in 2016, from 1973 to 2010, 44 countries in the world permitted the dumping of about 30 billion tons of dredgedobjects and substances into the sea. The total volume of objects and substances during the above period tended to increase gradually, from 100 million tons/year (1972) to 800 million tons/year (2010). In 2012, China permitted the dumping of about 246 million tons of dredged objects and substances (of which about 59.5 million tons were dumped into the East Sea); the US about 55 million tons; the Netherlands about 25 million tons; the UK about 13 million tons. Also, according to the IMO, the volume of dredged materials permitted for dumping at sea accounts for about 80 - 90% of the volume of objects and substances dumped at sea.

Dumping activities at sea have actually taken place in Vietnam before the Law on Marine and Island Resources and Environment was enacted, such as: Dredging to create a path for ships to enter and exit when building Cai Lan port, near Bai Chay bridge area; objects and substances from dredging activities at Lach Huyen transit port, Hai Phong with a total volume of objects and substances dumped of nearly 40 million m^3 and implemented according to the request-grant mechanism.

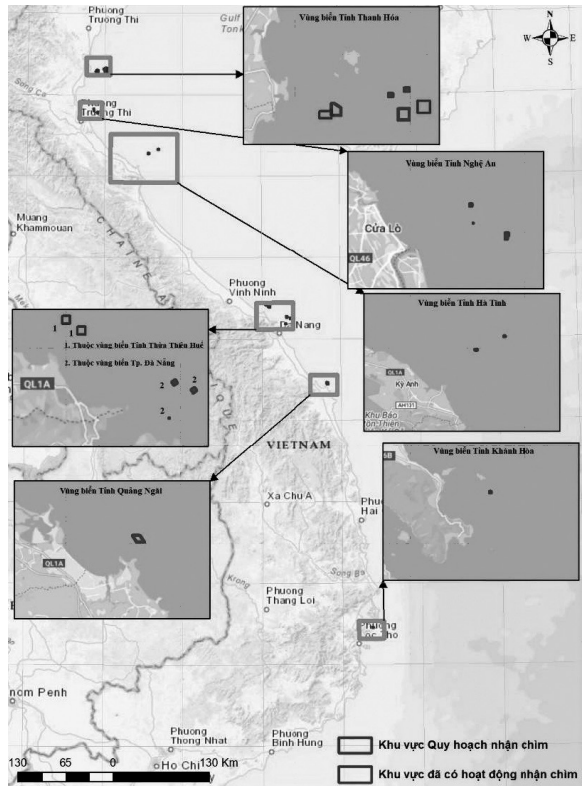
2.2. Current situation of dumping at sea in Vietnam

Along with socio-economic development, the need for dumping, especially dumping dredged materials from shipping channels and ports into the sea in Vietnam has been increasing rapidly in recent times.

The Northern sea area includes provinces of Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, all of which have maritime activities, along with the need for dredgingin maritime routes and seaports. Although the need for dredging in maritime routes of the Northern



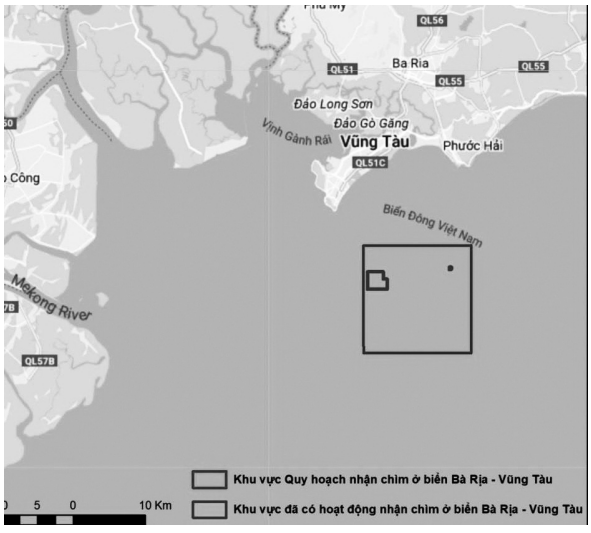
Areas for dumping and planned for dumping dredged objects and substances at sea from Quang Ninh to Ninh Binh



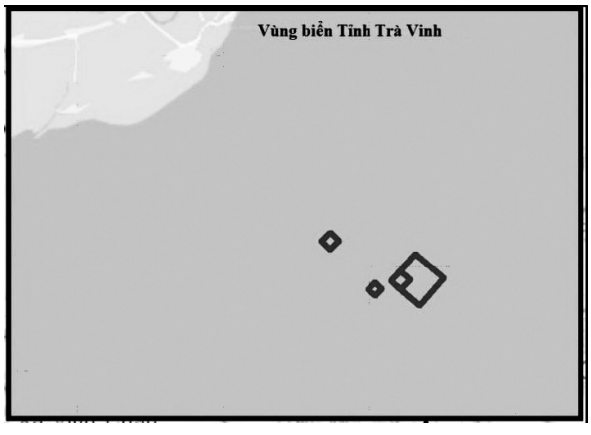
Areas for dumping and planned for dumping dredged objects and substances at sea from Thanh Hoa to Binh Thuan

sea area is large, up to nearly 40 million m^3, especially in Quang Ninh and Hai Phong areas, up to now, the number of provinces with Permits for dumping dredged materials at sea has only been granted in Hai Phong sea area (3 Permits with a dumping volume of nearly 6 million m^3), remaining provinces have chosen the option of dumping dredged materials onshore.

The North Central sea and Central coastal region include 14 provinces from Thanh Hoa to



Areas for dumping and planned for dumping dredged objects and substances at sea from Ba Ria - Vung Tau to Ho Chi Minh city



Areas for dumping and planned for dumping dredged objects and substances at sea from Tien Giang to Kien Giang

Binh Thuan, with a total volume of dredging of about 14.7 million m^3, of which Thanh Hoa and Ha Tinh provinces are the two areas with the largest dredging demand. According to collected results, from 2016 to present, in the North Central sea and Central coastal region, there are currently 33 Permits for dumping at sea issued by the MONRE (now the MAE) and Provincial People's Committees, calculated from the time the Law on Marine and Island Resources and Environment took effect on 1st July 2016. Dumping of dredged materials at sea is mainly in sea areas of Thanh Hoa province (7/33 Permits), Nghe An (5/33 Permits), Ha Tinh (3/33 Permits), Quang Ngai (3/33 Permits), Quang Nam (1/33 Permits) and Da Nang city (8/33 Permits).

The Southeast sea area includes provinces of Ba Ria - Vung Tau and Ho Chi Minh city. Currently, only Ba Ria - Vung Tau has dredging activities and the need for dumping dredged materials; the volume of dredged materials dumped in this area is over 15 million m^3 (7 Permits).

The Southwest sea area includes 7 provinces from Tien Giang to Kien Giang. This is an area with a great need for dredging, especially at seaports of the Duyen Hai Power Center - where the sedimentation rate is high. In this area, about 30 million m^3 (12 Permits) of dredged materials has been dumped into the sea of Tra Vinh.

After the Law on Marine and Island Resources and Environment 2015; Decree No. 40/2016/ND-CP and related legal regulations came into effect, the MONRE (now the MAE) issued 45 Permits for dumping about 107 million m^3 of dredged materials from ports and channels; local coastal authorities issued about 15 Permits for dumping at sea.

3. SOME DIFFICULTIES AND OBSTACLES

In the process of implementing legal regulations on issuing Permits for dumping at sea in Vietnam, there are some difficulties and obstacles as follows:

Firstly, coordination with ministries, sectors and local authorities in the appraisal of dossiers applying for Permits for dumping at sea: During the appraisal of dossiers, the MAE issues documents requesting opinions from the Ministry of Construction, Ministry of National Defence and Provincial People's Committees. However, the time to respond to documents from ministries is often slower than the time prescribed in Decree No. 40/2016/ND-CP dated 15 May 2016 of the Government.

Secondly, according to provisions of Clause 2, Article 7, Decree No. 57/2024/ND-CP, Provincial People's Committees shall prepare, announce, and publicly post a list of areas and locations for dumping dredged materials at sea, including sea areas beyond 6 nautical miles on their portal/website and at the headquarter according to the form prescribed in the attached Appendix. However, currently, very few localities are able to implement aboveprovisions.

Thirdly, provisions of the Law on Marine and Island Resources and Environment; Decree No. 40/2016/ND-CP dated 15 May 2016 of the Government have many shortcomings.

Duration of the Permit for dumping at sea: According to provisions of Clause 2, Article 59 of the Law on Marine and Island Resources and Environment, the duration of the Permit for dumping at sea is not more than 2 years and can be extended once but not more than 1 year. In reality, the dumping of dredged materials for maintenance of shipping routes and seaports usually takes place annually, therefore, above provisions on the duration of the Permit for dumping at sea will lead to organizationsand individuals having to apply for a Permit for dumping at sea every year or every 2 years.

Appraisal process: The Law on Marine and Island Resources and Environment stipulates that the MAE and Provincial People's Committees are competent authorities to issue the Permit for dumping at sea. However, procedures for issuance, re-issuance, extension, amendment, supplement, permission to return of the Permit for dumping at seastipulate a common process for the MAE and Provincial People's Committees. This causes difficulties for local authorities with inconsistent appraisal methods (some local authorities ask for opinions from departments and sectors; some local authorities hold appraisal meetings; some local authorities establish appraisal councils, etc.).

Methods of dossier appraisal: According to Clause 2, Article 57, Decree No. 40/2016/ND-CP dated 15 May 2016 of the Government, the dossier appraisal is carried out by the dossier receiving agency, if necessary, opinions of relevant agencies and on-site inspection are sought. However, in practice, the appraisal of dossiers applying for a Permit for dumping at sea requires opinions of domestic and foreign scientists and experts.

Technical provisions on dumping at sea: The sea area for dumping is mostly near-shore sea area (sea area from 3 nautical miles to 24 nautical miles from the coast). According to QCVN 10:2023/BTNMT - National technical regulation on seawater quality in near-shore areas, there is a lack of some specific parameters to assess and monitor the quality of the seawater environment in the dumping area (for example, total suspended solids TSS parameter).

Charges for issuing a Permit for dumping at sea: According to the Law on Fees and Charges, the Law on Marine and Island Resources and Environment stipulates that organizations and individuals who are granted a Permitfor dumping at sea must pay charges for issuing a Permitfor dumping at sea. However, the appraisal process to issue a Permit must go through many steps such as on-site surveys, inviting appraisal experts, etc. Therefore, it is recommended that the competent authority adjust provisions to collect appraisal charges to partially offset the budget expenditure for the appraisal of applications for a Permit for dumping at sea.

Fourthly, the examination and supervision mechanism during the dumping process has not been clearly defined, with the project owner being responsible for implementation or independent supervision conducted by state management agencies; equipment for examination and supervision, human and financial resources for marine environmental supervision activities are still lacking and weak; the supervision of the itinerary and volume depends on the local port authority.

4. PROPOSED SOLUTIONS FOR THE COMING TIME

In order for activities of dumping at seain Vietnam to be truly effective, in the coming time, the Department of Agriculture and Environment of coastal provinces and cities need to advise the Provincial People's Committee to prepare, announce, and publicly post a list of areas and locations for dumping dredged materials at sea according to current regulations, as a basis for implementation at the same time as preparing, announcing, and publicly posting the list and dumping points, facilitating local authorities to seek opinions from relevant ministries, sectors and have a dossier to send to the MAE for consideration.

In 2024, the MONRE completed the summary of the implementation of the Law on Marine and Island Resources and Environment, and submitted Report No. 303/BC-BTNMT dated 31 December 2024 to the Government. Implementing the Government's direction, the MAE is currently presiding over and coordinating with relevant ministries, sectors and local authorities to propose amendments and supplements to the Law on Marine and Island Resources and Environment in accordance with provisions of the Law on Promulgation of Legal Documents, and reports to the Government for consideration and decision. The Viet Nam Agency of Seas and Islands has compiled and is considering amending and supplementing a number of contents such as: Duration of the Permit to suit reality; Regarding the appraisal process for issuing a Permit for dumping at sea, study to integrate contents of 02 sets of documents: (1) Project for dumping at sea, and (2) Environmental impact assessment report into one set of documents to be submitted to the competent authority for consideration and appraisal in order to create favourable conditions, reduce administrative procedures, and create motivation for businesses, organizations, individuals... In addition, it is recommended that the Government includesprovisions on paying charges for issuing a Permit for dumping at sea in the list of the Law on Fees and Charges.

Regarding technical provisions on dumping at sea: The sea area for dumping is mostly near-shore sea area (sea area from 3 nautical miles to 24 nautical miles from the coast) and the examination and supervision mechanism during the dumping process. Currently, the Vietnam Agency of Seas and Islands has the plan to develop a national technical regulation on seawater quality in dumping activities and the process of supervision of the implementation of dumping activities at sea■

SB62 Conference on global climate change response

The technical mid-year meetings like SB62, the 62nd session of the Subsidiary Bodies to the UN Framework Convention on Climate Change (UNFCCC) was known as the Bonn Climate Change Conference, opened on June 16th in Bonn, Germany and served as the only formal negotiation space ahead of COP30.

The SB sessions are where Parties revisit technical details and unresolved issues from previous COPs and where groundwork is laid for decisions to be negotiated and adopted at the COP that follows later each year. This year, SB62 took on heightened significance: Coming off the back of a bruising COP29 and amid growing geopolitical and economic challenges, it tested the multilateral climate regime's ability to rebuild trust and deliver concrete progress. With COP30 envisioned as a "pivot point" for climate action by the Brazilian Presidency, the SB62 outcomes was critical in defining the shape of negotiations in Belém. The Presidency has made clear its desire to elevate adaptation as a key priority at COP30, making it a likely focal point at SB62 as countries work to build momentum and consensus ahead of the summit.

SB62 refered to the 62nd session of the two permanent bodies under the UNFCCC: The Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI).

While the SBs don't adopt decisions, they are vital for the functioning of the international climate regime, featuring technical negotiations, which fall under the responsibility of the two SB chairs, and in-session workshops, dialogues and other mandated events. At SB62, negotiators worked in multiple parallel tracks, developing draft conclusions that was further negotiated at COP30 in Belém, Brazil for formal adoption as decisions.

For adaptation, this technical work is crucial: it's where frameworks for planning, tracking, financing, and implementation, are assessed and refined. The outcomes of SB62 shaped how adaptation was framed and prioritized in the run-up to COP30, but potentially far beyond. SB62 also represented a crucial opportunity to rebuild trust and enhance collaboration among Parties following the bruising COP29 negotiations. COP29 left many developing countries disillusioned, with concerns about transparency, equity, and an overrepresentation of fossil fuel lobbyists. In response, the Brazilian COP30 Presidency had emphasized restoring a productive and constructive negotiation environment at SB62, one that can foster unity and concrete outcomes. This setup of different observers, Parties, and UN staff at the conference is identical to the COP and the badge system identifying individuals' respective status is the same.

While negotiators negotiate and observers observed, there are opportunities for all groups to participate in side events, informal consultations, workshops, and bilateral meetings. While negotiations were typically closed to the public, many side events and briefings are livestreamed, offering a window into the process.

THE GLOBAL GOAL ON ADAPTATION (GGA) AND THE UAE-BELÉM WORK PROGRAMME

A major focus at SB62 is advancing operationalization of the Global Goal on Adaptation (GGA) – established under Article 7 of the Paris Agreement to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change. At COP28, countries adopted the UAE Framework for Global Climate Resilience, aimed at defining and measuring progress towards the GGA, and launched the UAE-Belém work programme. The central task of the work programme is to develop a robust set of no more than 100 indicators that can measure and track collective progress toward the targets agreed in the framework, across areas like health, food systems, biodiversity, infrastructure, and governance. Technical experts have been working since late 2024 to define a short-list of indicators from the thousands submitted by Parties and Observers, and SB62 hosted both technical discussions and political negotiations to assess and refine these indicators. The priority (and challenge) was to create a set of indicators that are specific enough to be meaningful, yet flexible enough to reflect local realities. Such a shortlist can never be exhaustive in capturing all aspects of climate resilience, so we can expect clashes over inevitable compromises and trade-offs.

NATIONAL ADAPTATION PLANS (NAPS)

NAPs are central to how countries prepare for and respond to climate impacts. Developed under the UNFCCC, they help governments assess risks, set priorities, and guide long-term adaptation across sectors. NAPs also play a crucial role in unlocking

Delegates gather to hear about the roadmap to achieving USD1.3 trillion in climate finance

finance and integrating adaptation into national development. At SB62, countries reviewed progress on NAPs, focusing on closing gaps in finance and technical support, strengthening institutional capacity, and moving from planning to real-world action. While many countries have made progress, turning plans into funded, effective projects remains a challenge. SB62 spotlighted these barriers and push for more accessible and coordinated support, including through the Green Climate Fund. In addition, SB62 may see a push to assess how adaptation features in third-generation NDCs, due this year.

CLIMATE FINANCE AND THE BAKU TO BELÉM ROADMAP TO $1.3 TRILLION

Although not formally negotiated, adaptation finance was a key focus at SB62, as observers call for clearer, more effective pathways for delivering support to those most vulnerable to climate impacts. Central to this effort is the Baku to Belém Roadmap, which aims to scale up climate finance for developing countries – amounting to at least $1.3 trillion annually by 2035. The Roadmap promotes low-emission, climate-resilient development by supporting the implementation of NDCs and NAPs. It calls for a mix of grants, concessional finance, and non-debt-generating instruments to meet the diverse financial needs of developing nations, especially those on the front lines of climate change. However, major gaps remain in how this finance is accessed, allocated, and tracked. In Bonn, Parties discussed the transparency and effectiveness of climate finance flows, including how resources could more reliably reach the communities that need them most. They are also expected to discuss the implications of the current adaptation finance doubling goal expiring in 2025, and the urgent need to establish a new, clearly defined adaptation finance target to guide funding flows in the post-2025 period.

TRANSFORMATIONAL ADAPTATION

At SB62, parties resumed deliberations on transformational adaptation, a key issue under the GGA which proved deeply divisive at COP29. Building on the 2024 UNFCCC technical paper outlining dimensions like depth, scale, speed, and sustainability, discussions focused on how to operationalize transformational change. While the UAE framework emphasizes both "long-term transformational and incremental adaptation", it left the question of means of implementation unaddressed. This leaves developing countries facing a core challenge: how to address the GGA targets without financial, technological, and capacity building guarantees.

Linked to this is the Baku Adaptation Roadmap (BAR), adopted at COP29 to guide GGA implementation. Though it aimed to integrate adaptation across key systems like food, water, and biodiversity, it remains vague. Debate continues over unresolved elements from paragraph 38 of Decision 2/CMA.5, especially how to align indicators with reporting, finance, and the Global Stocktake. Tensions also persist over the reframing of contested

means of implementation indicators as broader "enablers of implementation," which many developing countries see as weakening accountability. At SB62, parties needed to clarify the structure and purpose of the BAR to ensure it drives concrete, supported action not just reporting.

MONITORING, EVALUATION AND TRANSPARENCY

At SB62, countries focused on how to track and report real progress on adaptation. A key part of this involves updates to the Enhanced Transparency Framework (ETF) under the Paris Agreement. The UNFCCC Secretariat reported on new tools to support countries' adaptation reporting and training for experts reviewing the first Biennial Transparency Reports submitted in 2024. Negotiators also discussed how to strengthen support for developing countries, including financial help and clearer roles for the Consultative Group of Experts, which advises on reporting.

ADAPTATION COMMUNICATIONS

Parties were expected to exchange views on how they are preparing and updating their adaptation communications (voluntary reports that highlight national priorities, actions, and support needs). These communications inform planning and resource allocation.

HOW SB62 LOOKS AHEAD TO COP30

SB62 also looked ahead to COP30 and Brazil's incoming presidency. Brazil played an active role in Bonn this month as participants shape the political agenda and operational planning for the November conference in Belém. This includes some lingering issuesed from COP29, often called "hangover negotiations" that were not finalised last year in Azerbaijan. They became part of the roadmap from Baku to Belém. This included the climate finance goal and pathways for implementing the Global Stocktake. These unfinished negotiations added some complexity to Brazil's presidency of this year's COP, adding pressure to move the agenda forward and rebuild trust among the parties particularly between high-and low-income nations, where divided over finance, equity, and accountability remain stark. We can expect Brazilian leaders to use SB62 as a meeting ground for informal consultations, bilateral meetings, and thematic dialogues that will help set the tone for COP30.

CONCERN AT THE BONN CLIMATE CONFERENCE

While SBs are more technical, they still bring together a broad range of observers, including NGOs, advocates, local governments, and academic institutions. Concern is attending SB62 because it serves as a vital platform for engagement in the heart of the UNFCCC's negotiation process. Observer constituencies are also a key factor in these meetings. While they're not formal negotiators, they work together as collective voices that call attention to key matters and advocate for certain outcomes through evidence-based research, community perspectives, and policy proposals. It's a reminder that civil society helps to drive both ambition and accountability.

THE SHARM EL-SHEIKH DIALOGUE

The Sharm el-Sheikh Dialogue was established as part of the 2015 Paris Climate Agreement. It's often mentioned alongside the Paris agreement's Article 2.1c, which lays out the aim to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by… making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. This is obviously an "easier-said-than-done" scenario, and so the Sharm el-Sheikh Dialogue became a process for establishing a common understanding between countries. The first SeSD workshops were held in 2023 and two will be held this year, starting with SB62. UNFCCC notes that these workshops "have made some headway," but "key questions remain unanswered" and parties are still trying to achieve a common ground on understanding the scope of Article 2.1c, so that will be a key aim for this year's dialogues.

PROGRESS MADE ON INTERNATIONAL CARBON MARKETS UNDER ARTICLE 6

Delegates made important strides on key technical aspects of Article 6, including carbon credit authorization, activity scope, the international carbon market registry and more. Constructive discussions in Bonn clarified positions on Article 6.2 and 6.4 ahead of COP29. Delegates also agreed to hold a workshop to further progress technical work on Article 6.2 and 6.4 ahead of November. As a result, they were better placed to meet in Baku ready to finalize an outcome and move towards better carbon markets. In the lead up to COP29, additional work on Article 6.4 will move forward. The UN Body responsible for operationalizing a new global carbon market under the Paris Agreement met twice ahead negotiations in Baku, to finalize recommendations on methodologies and emission removals. Feedback gathered from Parties and stakeholders at an engagement event during the June Climate Meetings will be incorporated into these recommendations. The Supervisory Body also aims to finalize a Sustainable Development Tool in the run up to COP29, to establish environmental and social safeguards. Completing the remaining elements

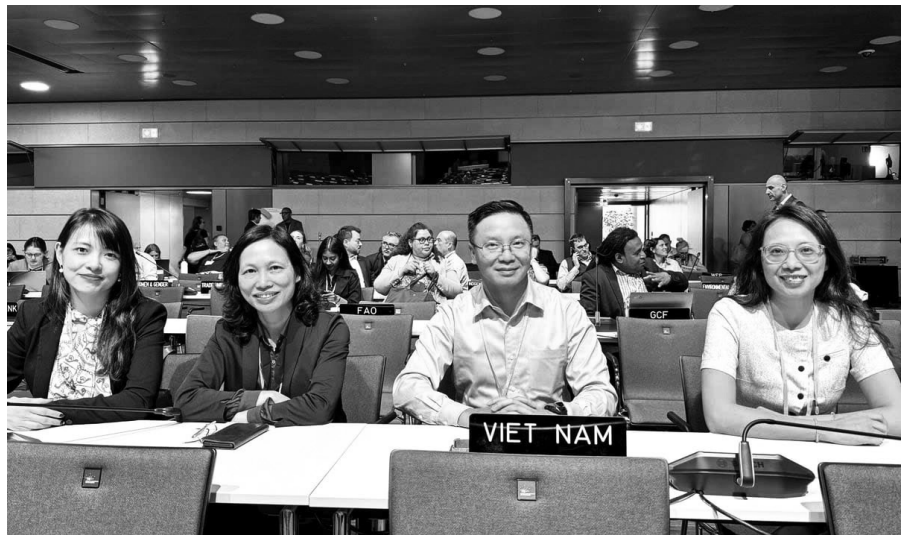
on Article 6 in Baku will unlock further funding for national climate plans and adaptation.

OTHER ISSUES AND EVENTS AT THE JUNE MEETINGS:

The final review of the implementation of the enhanced Lima work programme and its Gender Action Plan (GAP) was initiated at the June Meetings identifying progress, challenges, gaps and priorities in implementing the GAP, and further work to be undertaken. The discussions started at this session set the scene for developing the tools to embed gender in forthcoming NDCs, NAPs and transparency reports.

The Standing Committee on Finance advanced preparations for the 2024 Forum on gender-responsive financing. Taking place from 2nd – 3rd September in Arusha, Tanzania, the Forum will highlight the critical importance of gender-responsive finance in achieving low-emission climate-resilient development and poverty eradication that will be equitable and inclusive.

Parties achieved a breakthrough under the Sharm el-Sheikh joint work on implementation of climate action on agriculture and food security, agreeing on a road map for the work ahead until COP31, using workshops on agreed topics, an annual synthesis report on agriculture and food security published by the secretariat, and an online platform for sharing information on projects, initiatives and policies for climate action to address issues related to agriculture and food security.



Vietnamese delegation attended the consultation meetings of the SB62

The Ocean and Climate Change Dialogue took place over two days at the June Climate Meetings, with a focus on two key topics – marine biodiversity conservation and coastal resilience, and ocean energy technologies.

The Action for Climate Empowerment (ACE) Hub hosted an event to bring young people together for skills-building and knowledge-sharing. The focus this year was on local action. Fifty young people – 25 from around the world and 25 from Germany – came together to develop the skills they need to lead climate initiatives in their communities.

The High-Level Climate Champions, Nigar Arpadarai (Azerbaijan) and Razan Al Mubarak (United Arab Emirates), organized a series of events that explored how businesses, cities, regions, Indigenous Peoples and civil society are working alongside governments to deliver ambitious climate action ahead of COP29.

The third Glasgow Dialogue on loss and damage at the June Meetings discussed the coordination arrangements for the Fund responding to loss and damage, assessed progress made and developed further recommendations.

ACTIVITIES OF THE VIETNAMESE NEGOTIATING DELEGATION AT SB62

The head of the Vietnamese Delegation - Deputy Director of the Department of Climate Change Le Ngoc Tuan attended the consultation meetings of the SB62. Vietnam and other countries discussed to add more content to the SB62 agenda. In addition, Mr. Tuan also attended the informal consultation meeting of the COP30 President with the heads of negotiating delegations on the contents towards COP30. Before that, there was a meeting of national focal points participating in the Global Cooling Commitment.

Members of the Department of Climate Change also attended the Joint Crediting Mechanism (JCM) Partnership Meeting hosted by Japan. Currently, 31 countries have signed the JCM with Japan, including areas such as energy, agriculture, waste management and land use. At the meeting, the Vietnamese representative proposed that the Japanese side support Vietnam in implementing NDC 3.0 through implementing projects within the JCM framework and integrating them into the financial roadmap for implementing the NDC that Vietnam is developing. The Japanese side agreed to discuss with the JCM focal point of Vietnam to propose potential projects■

HIỀN NHÂM

THE CONVERGENCE OF CRIMES IN THE NATURAL RESOURCES SECTOR: A Proposal for Comprehensive Policy Responses

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In the context of increasing globalization and complex climate change, the illegal exploitation of natural resources - including wildlife trafficking, illegal logging, mining, illegal fishing, and unsustainable land conversion - has emerged as a serious threat to global ecosystems. These activities not only harm the environment but also contribute to social instability, exacerbate food insecurity, undermine economies, and erode efforts toward sustainable development.

However, in many countries, including Vietnam, policy and legal responses to this type of crime remain slow and fragmented. Current legislation has not kept pace with the trans-national, diverse, and highly adaptive nature of resource-based crime. In addition, weak coordination among domestic authorities- and across borders - creates gaps that criminals can readily exploit. According to the 2020 INTERPOL-UNEP report, the illegal trade in natural resources is now the world's third largest area of transnational organized crime, surpassed only by drug trafficking and counterfeit goods, with annual revenues estimated turnover of between 110 and 281 billion USD per year [2].

In light of this reality, the article proposes a number of key policy solutions to enhance the ability to respond to the convergence of crimes in the natural resources sector. The recommendations are based on an analysis of the characteristics, impacts and current legal context, aiming toward a comprehensive, multi-sectoral, and sustainable response strategy.

1. THE CONVERGENCE OF CRIME – A GROWING THREAT

The "convergence of crimes" refers to the intersection of various criminal activities-from drug, arms, and human trafficking to the illegal exploitation of natural resources-forming complex and multi-layered organized crime networks. These organizations are becoming increasingly agile and decentralized, leveraging modern technology and gaps in state governance to expand their operations, particularly in resource-rich regions with weak governance.

Traditional criminal organizations that once focused on drug trafficking are now shifting toward gold, timber, and wildlife trade due to higher profits and lower risks. They exploit existing supply chains, transportation infrastructure, and social media networks to legitimize operations, launder money, and sustain cross-border activities. The result is a transnational crime network capable of seriously threatening biodiversity, human security, and regional economies.

In Brazil, especially in the Amazon and Cerrado regions-the convergence of deforestation, illegal gold mining, and wildlife trafficking with other crimes such as human trafficking and drug trade has become widespread [4]. Criminal groups use profits from drug trafficking to invest in mining equipment and operate illegal gold mines, often using the same routes to traffic both gold and drugs. Remote border areas with limited state presence have become hotspots for converging criminal activities.

In addition, illegal gold mining serves as an effective tool for money laundering due to its cash-intensive nature and ease of legitimization through trade. Investigations in South America have uncovered billions of USD laundered through illicit gold mining and trade activities [1].

This situation is not limited to South America. In Southeast Asia, wildlife trafficking, illegal logging, and illicit mineral extraction are also intertwined with other criminal activities such as drug and human trafficking-particularly in the Golden Triangle and border regions between Vietnam, Laos, and Cambodia [3].

2. IDENTIFYING CHARACTERISTICS AND IMPACTS OF THE CRIME CONVERGENCE

2.1. Common features of the crime convergence

Crime convergence is a global phenomenon, with evidence found across many countries, reflecting diverse economic, social, and political contexts. While its manifestations vary by region, several common characteristics of crime convergence involving natural resource exploitation can be identified from criminological, legal, and global perspectives:

Exploitation of vulnerable populations: Criminal organizations often prey on poverty, lack of economic opportunities, and weak access to education and healthcare in remote and marginalized communities. Local residents may be drawn into illegal supply chains or transportation networks, becoming unwilling participants in criminal activities. In the Amazon or Southeast Asia, many indigenous communities are recruited into illegal gold mining, wildlife poaching, or timber smuggling due to the absence of sustainable livelihoods.

Weak or fragmented legal frameworks: Legal shortcomings - such as lenient penalties, overlapping

Ivory trafficking is one of the serious crimes prohibited by law

mandates among enforcement agencies, or absence of specific environmental crime legislation - create loopholes that criminals can exploit. In some countries, acts such as illegal logging, unregulated fishing, or illicit mining are still not classified as serious crimes, leading to light sanctions and weak deterrence.

Use of natural resource profits to finance serious crimes: The extraction of timber, gold, gemstones, and wildlife often yields massive profits with relatively low legal risks compared to drug or arms trafficking. Criminal organizations treat these sectors as cash engines for broader operations. Gold and gemstones are typically traded in cash due to their traceability challenges, while minerals and timber can be laundered using forged permits or export documents. The profits are then funneled into the financial system, real estate, or cross-border trade. This significantly increases the reach and impact of organized crime networks. In South America, drug cartels have been found using gold mining supply chains to conceal cash flows and fund cocaine trafficking. In East Africa, proceeds from illegal ivory trade are suspected to fund armed groups.

Cross-border coordination that bypasses traditional legal boundaries: Resource-based crimes rarely operate within the confines of a single country. Instead, they exploit weak international cooperation to move, legitimize, or launder illegally obtained goods. Their methods include using international smuggling routes to move illicit resources through multiple transit countries; employing shell companies to obscure ownership and financial trails; and exploiting legal inconsistencies among nations to avoid prosecution. For example, illegal timber from Laos may be transported through Thailand, legalized in Vietnam, and exported to Europe or the U.S. as "plantation timber." Each country controls only a segment of the chain, making it difficult to trace back to the origin.

2.2. Some key impacts of crime convergence

Decline in biodiversity: The convergence between illegal resource extraction and organized crime is now one of the leading causes of global biodiversity loss. The trafficking of wildlife, rare timber, and prohibited marine species has pushed many species to the brink of extinction. Ecosystems - from the Amazon rainforest and Southeast Asia's primary forests to coral reefs in Africa - are being severely degraded by these activities. This results in ecological imbalances, disrupts food chains, and threatens the livelihoods of millions of people who depend on natural resources, especially poor local communities.

Economic instability and regional insecurity: Transnational criminal activity in the resource sector not only harms the environment but also erodes the legal economy and threatens regional security. When criminal groups control the extraction and trade of natural resources, state revenues suffer due to tax evasion and commercial fraud. These illicit profits are often used to fund armed groups, insurgents, or other criminal networks, contributing to prolonged instability in resource-rich areas such as Central Africa, Southeast Asia, and South America. This shadow economy undermines social order and weakens the ability of local authorities to govern and respond effectively.

Increased corruption and weakened governance: Organized crime in the resource sector frequently relies on and fosters corruption to conceal or legitimize illegal activities. Criminals bribe forest rangers, customs officers, police, and even high-level officials to facilitate the transport, trade, and export of illegally sourced goods such as timber, minerals, or endangered wildlife. This not only obstructs investigations and prosecutions but also undermines the entire public governance system, rendering the rule of law ineffective. When citizens witness the government's inability - or complicity - in dealing with wrongdoing, trust in the state deteriorates, creating a vicious cycle of crime, corruption, and social injustice.

Exacerbation of social inequality and resource conflicts: Natural resources are a common good, yet when they are captured and exploited illegally by organized groups, it is often the local population - especially vulnerable communities and ethnic minorities - who suffer the most. They lose land and forests, are forcibly displaced, or are excluded from decisions affecting their environment. Inequality deepens as a small minority profits from criminal activities while the majority bears the environmental, economic, and social costs. Such injustices can ignite resource conflicts, land disputes, weaken social cohesion, and provide fertile ground for the rise of extremist movements.

3. POLICY PROPOSALS TO ADDRESS CRIME CONVERGENCE

In the face of rising illegal resource extraction linked to transnational organized crime, building a comprehensive response strategy is an urgent necessity. The following policy solutions should be implemented in a coordinated, targeted, and multisectoral manner to weaken criminal networks and enhance sustainability in resource governance:

First, strengthen law enforcement effectiveness and interagency coordination. The current enforcement systems suffer from fragmented information and uneven capacity across agencies. Therefore, it is essential to establish mechanisms for transparent, rapid, and secure information sharing among law enforcement, environmental, judicial, and financial authorities. Investigations and prosecutions must go beyond traditional approaches that target only individuals caught at the scene. Instead, it is necessary to focus on dismantling intermediaries and masterminds – entities that play a decisive role in the operational chain of resource crime networks.

Second, strengthen the legal framework and raise the level of environmental crimes. Many countries still classify environmental crimes as administrative violations or minor criminal offenses, making the handling of them less deterrent. It is necessary to upgrade the severity of acts such as illegal exploitation, transportation, and trafficking of natural resources, classifying them as serious crimes equivalent to drug crimes or money laundering. This not only contributes to unifying awareness in the legal system but also creates conditions for expanding international cooperation in cross-border investigation and prosecution.

Third, promote sustainable development and support livelihoods in local communities. One of the root causes of people engaging in illegal mining activities is the lack of legal livelihood opportunities. Therefore, it is necessary to expand sustainable rural economic development programs, creating conditions for local people to access stable, environmentally friendly jobs. At the same time, it is necessary to integrate the goal of protecting natural resources into socio-economic development policies, especially in areas near forests, national parks and reserves.

Fourth, enhance transparency and control corruption in the resource supply chain. Corruption in regulatory agencies and law enforcement agencies that facilitate resource crime continues to be rampant. Therefore, it is necessary to strengthen internal monitoring measures, enhance accountability and apply technology to effectively control the resource supply chain – from mining, transportation to consumption.

Fifth, promote international and regional cooperation. Due to the transnational nature of resource crime, it is difficult for a single country to effectively deal with it. Establishing bilateral and multilateral cooperation mechanisms on investigation, extradition and information sharing is essential. Existing networks such as INTERPOL, CITES or the ASEAN Wildlife Enforcement Network (ASEAN-WEN) should be fully utilized, while promoting Vietnam's role in regional and global initiatives on environmental crime prevention.

Sixth, strengthen the legal framework and raise the level of environmental crimes. Many countries still classify environmental crimes as administrative violations or minor criminal offenses, making the handling of them less deterrent. It is necessary to upgrade the severity of acts such as illegal exploitation, transportation, and trafficking of natural resources, classifying them as serious crimes equivalent to drug crimes or money laundering. This not only contributes to unifying awareness in the legal system but also creates conditions for expanding international cooperation in cross-border investigation and prosecution.

CONCLUSION

The convergence of natural resource crimes and organized crime networks presents a global challenge. This is not merely an environmental issue - it is a matter of security, development, and justice. To respond effectively, a multidimensional strategy is required, spanning law, enforcement, international cooperation, and community development. Only by recognizing the seriousness and cross-sectoral nature of this threat can we begin to dismantle the sophisticated criminal networks that are expanding in scale and influence■

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International experience in applying artificial intelligence (AI) in marine biodiversity management and recommendations for Vietnam

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1. THE ROLE OF MARINE ARTIFICIAL INTELLIGENCE TECHNOLOGY

Resolution No. 57-NQ/TW dated December 22, 2024, issued by the Politburo on breakthrough development in science, technology, innovation, and national digital transformation, emphasized the urgent need for digital transformation in the management of seas and islands [1]. Besides, Resolution No. 36-NQ/TW dated October 22, 2018, on the "Strategy for Sustainable Development of Vietnam's Marine Economy to 2030, with a Vision to 2045," set forth goals associated with the conservation of marine biodiversity and increasing the area of marine protected zones to 6% by 2050 [2]. To effectively manage marine biodiversity in service of sustainable marine economic development, it is imperative to achieve breakthroughs in digital transformation, with the application of artificial intelligence (AI) as an urgent and critical need.

Globally, many studies and practical applications have used AI to explore the vast ecosystems of the oceans [3,4,5]. Essentially, marine AI integrates advanced algorithms with marine science to analyze large datasets collected from ocean environments. These analyses lead to crucial insights into marine biodiversity, conservation efforts, and the impacts of climate change. Marine AI gathers data through innovative tools such as underwater drones, satellite imagery, and acoustic sensors. These technologies provide extensive information on oceanic conditions and marine organisms, including temperature, salinity, and behavioral patterns of aquatic species. Advanced processing techniques enable the effective analysis of complex marine datasets, which helps identify patterns and predict changes with high accuracy. This technology not only supports scientists in making informed decisions to protect marine ecosystems but also empowers the public to participate through citizen science initiatives and volunteer monitoring programs.

Figure 1. Diagram of marine artificial intelligence

2. BENEFITS OF AI TECHNOLOGY IN MARINE BIODIVERSITY MANAGEMENT

Marine AI technologies are being designed to support ocean conservation [3,5]. One innovative field in marine science is the development of AI-powered underwater drones. These devices can explore ocean depths that were previously inaccessible, capture detailed images, and collect critical data for mapping marine ecosystems. Using machine learning algorithms, these drones can identify and track species or detect signs of environmental degradation, which enables rapid response to conservation challenges.

Another innovation involves using AI to model the impacts of climate change on marine biodiversity. AI-assisted simulations can predict changes in habitats or the behavior of marine species due to climate change. This capability enhances the ability to implement proactive conservation strategies.

AI is also revolutionizing citizen science, as current platforms now allow volunteers to tag and classify marine wildlife through AI-guided applications, which can help enhance data collection for researchers.

The integration of these emerging technologies opens new avenues for engagement and continues to inspire collective action in protecting our oceans.

In the coming decade, marine artificial intelligence will be a beacon of hope for global conservation. Imagine AI-powered systems that can predict and mitigate the impacts of climate change on coral reefs, monitor illegal fishing activities, and model the migration patterns of endangered species. These advancements will enhance our understanding and protection of marine ecosystems. Marine AI technologies will empower scientists and conservationists with real-time data, promoting initiatives that are both proactive and preventative. Community participation becomes essential, as citizen scientists play a major role in data collection and verification. This collaborative approach will foster innovative solutions and drive governments to implement more effective conservation strategies.

3. SUCCESSFUL APPLICATIONS OF AI IN MARINE BIODIVERSITY CONSERVATION

In the field of marine conservation, AI has contributed to the successful protection of whales in the Gulf of St. Lawrence, Canada [3]. In 2017, North Atlantic right whales followed warming waters into the Gulf of St. Lawrence, hundreds of miles north of their usual habitat off the coast of Maine. The whales were pursuing their preferred prey (small crustaceans called copepods). As climate change warmed the northern waters, copepods shifted their range, and the whales followed. However, the Gulf is one of the busiest shipping corridors in the world, leading to a sharp increase in ship-whale collisions. Dozens of whales died from blunt force trauma or propeller strikes. A record number were also entangled in fishing gear, sometimes fatally. With only around 400 individuals remaining, the species, which already pushed to the brink of extinction by industrial whaling, faced a grave threat. Even the loss of a few dozen individuals posed a serious danger to such a small population.

Conventional conservation strategies struggled to keep up. Aerial surveys were costly and often hindered by poor weather, while whale sighting data used to alert ships was frequently outdated. In response, local biologists implemented a dynamic marine protected area strategy based on bioacoustics. They used underwater gliders equipped with hydrophones to monitor whale sounds over several years. This passive acoustic monitoring (PAM) allowed for continuous, more cost-effective, and accurate surveillance. These autonomous gliders (essentially the oceanic version of aerial drones) moved in pre-programmed paths, diving and surfacing every few hours to transmit data to onshore receivers (similar to mobile networks), which then relayed it to university laboratories. There, machine learning algorithms automatically analyzed the data to detect and identify the distinct calls of different whale species. Any detections were mapped and immediately sent to fisheries officials and ship captains. These AI-trained algorithms could accurately distinguish between whale species based on their vocalizations. Thanks to this AI application, no North Atlantic right whale deaths from ship strikes were recorded in 2020.

Another noteworthy initiative involves the use of AI-powered drones to combat illegal fishing [4]. In the Galápagos Islands of Ecuador, the government faces the daunting task of monitoring vast ocean territories to curb poaching and overfishing. Autonomous underwater vehicles (AUVs) equipped with AI technology are capable of covering long distances and detecting unauthorized vessels, providing a sustainable solution. These AI-driven AUVs have significantly reduced illegal activities, helping conserve marine ecosystems and supporting local fishing communities.

4. CHALLENGES OF AI IN MARINE BIODIVERSITY RESEARCH

Despite its many benefits, applying AI in marine biodiversity protection also presents significant challenges and raises ethical considerations. Using AI requires substantial resources and data, which may not be accessible in all regions, particularly those with limited scientific funding. Moreover, relying on automated systems raises concerns about privacy and data security, especially when it involves sensitive information related to marine territories and local communities.

From the ethical standpoint, AI deployment in marine environments must adhere to principles that prioritize ecological balance and respect the rights of indigenous and local populations. It is crucial that stakeholders work in partnership with local communities, incorporate their traditional knowledge, and ensure their voices are included in conservation dialogues. By addressing these challenges, we can harness the power of AI to promote sustainable interactions with the ocean and inspire collective action toward a healthier marine environment for future generations.

5. RECOMMENDATIONS FOR APPLYING MARINE AI IN VIETNAM

Building a "Smart Ocean" by integrating artificial intelligence into marine management in generaland

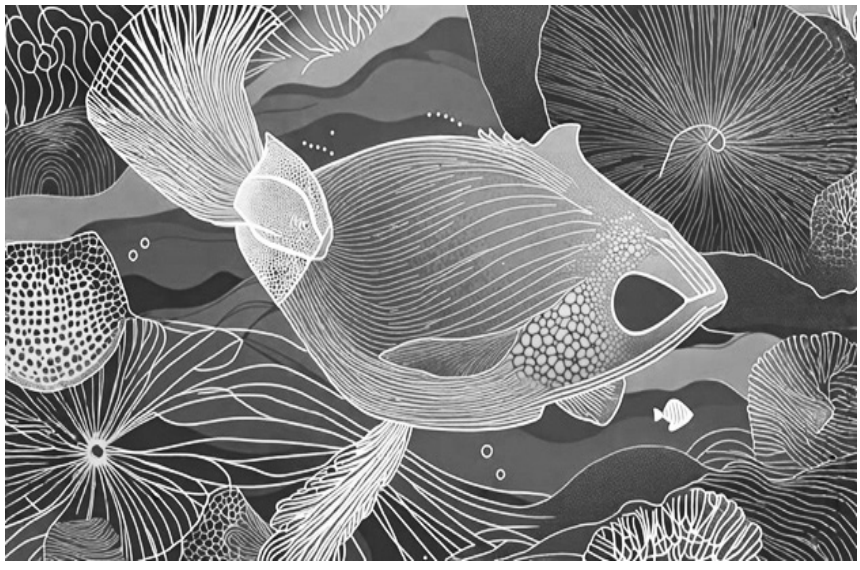

Figure 2. Using AI to identify fish behavior [4]

marine biodiversity conservation in particularwill enable Vietnam to sustainably harness its marine and ocean resources. By processing massive datasets with unprecedented speed and accuracy, marine AI provides essential insights for biodiversity conservation and ecosystem management. The combination of AI with traditional conservation approaches enhances the capacity to monitor marine life and address environmental challenges with more informed strategies. This innovative approach not only supports the work of scientists and conservationists but also creates opportunities for broader community engagement. Initiatives that apply AI to protect marine biodiversity offer a hopeful path for the future health of our oceans. Through collective action and ongoing innovation, we can ensure that Vietnam's marine ecosystems and protected areas are preserved for generations to come.

To strengthen marine biodiversity management and support the sustainable development of Vietnam's marine economy, the following recommendations are proposed:

Evaluate global experiences in applying AI to marine and biodiversity management, and use these insights to shape national AI-related policies and legal frameworks for marine governance.

Establish a national "Smart Ocean" program for Vietnam, focused on integrating AI into ocean and coastal management systems.

Review and revise existing national and ministerial science and technology programs on ocean governance, adding new tasks specifically related to marine AI.

Develop new research projects and programs that integrate AI with the management of marine protected areas (MPAs) and unique marine ecosystems such as coral reefs, seagrass beds, mangrove forests, and rare or endangered marine species.

Conduct scientific research to develop a foundation for applying AI in marine and ocean governance, marine economy sector management, and biodiversity conservation.

Establish specialized research teams, centers, and institutes dedicated to marine AI, along with smart devices for marine and seafloor monitoring.

Design a roadmap for AI application in marine and biodiversity management, outlining short-, medium-, and long-term implementation plans.

Provide training for marine professionals to equip them with AI knowledge and foster interdisciplinary collaboration with sectors like autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), remote sensing, and satellite technology.

Strengthen international cooperation in AI and marine biodiversity management to share expertise, tools, and best practices globally.

Mobilize financial resources to build the necessary infrastructure, equipment, and big data platforms for sustainable ocean governance■

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STRENGTHENING THE LEGAL FRAMEWORK FOR SUSTAINABLE TIDAL ENERGY DEVELOPMENT IN MARINE MANAGEMENT: International experience and recommendations for Vietnam

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Sustainable tidal energy is a form of renewable energy harnessed from the oscillation of sea levels caused by the gravitational forces between the Earth, the Moon, and the Sun. It is characterized by its stable periodicity, low emissions, and limited environmental impacts when deployed in a well-regulated manner. In many countries, including the European Union, Canada, and China, a relatively comprehensive legal framework has been established, encompassing clear licensing mechanisms, specialized environmental impact assessments, and financial incentive policies.

In contrast, the legal framework governing this sector in Vietnam remains in its nascent stages. Drawing upon international experiences, this article proposes a number of recommendations aimed at improving Vietnam's legal framework for the development of sustainable tidal energy, thereby contributing to the country's sustainable development goals.

TIDAL ENERGY IN THE CONTEXT OF SUSTAINABLE MARINE DEVELOPMENT

Tidal energy is a renewable resource generated from the movement of seawater driven by the gravitational interaction between the Earth, the Moon, and the Sun. As tides rise and fall, large volumes of seawater move, creating mechanical energy that can be converted into electricity using turbines and specialized generators. Unlike solar or wind energy, which are subject to significant fluctuations, tidal movements follow highly predictable and regular cycles that can be forecast decades in advance. As such, tidal energy is one of the most stable and reliable forms of renewable energy available today [5].

According to the United Nations World Commission on Environment and Development (Brundtland Report, 1987), sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Accordingly, sustainable tidal energy refers to the exploitation and utilization of tidal resources in a manner that ensures economic efficiency, marine environmental protection, and long-term ecological balance. The key pillars of sustainability in tidal energy development include:

Environmental Sustainability: Compared to conventional thermal or hydropower generation, tidal energy emits no greenhouse gases during operation and thereby contributes to climate change mitigation. However, the construction of barrages or turbines, if not carefully assessed, may adversely impact marine habitats, fish migration routes, or sediment transport [9].

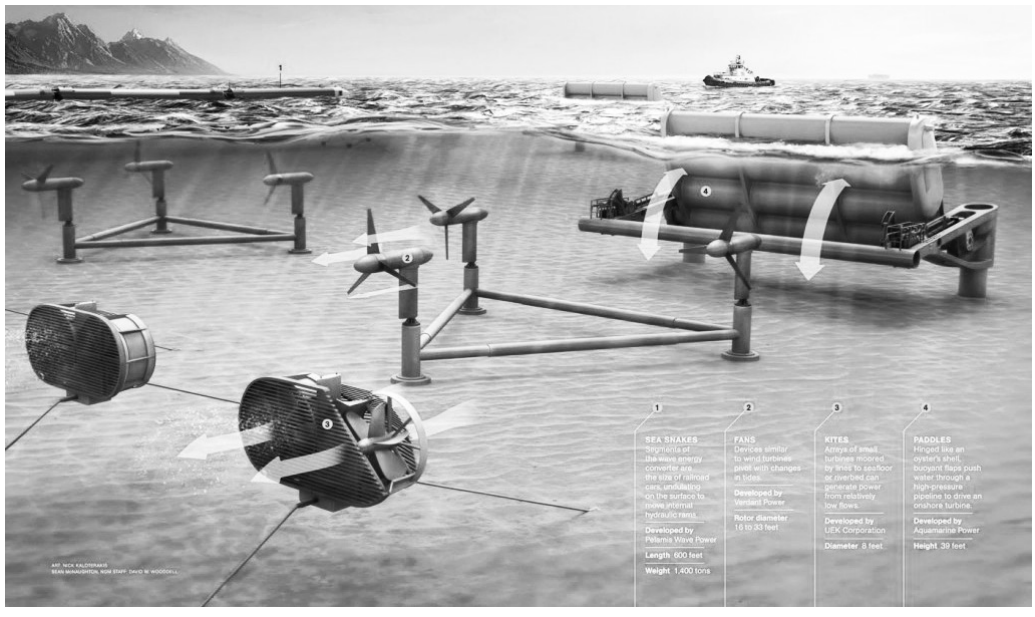
Economic Sustainability: Although the initial capital investment is high, tidal power systems have low operating costs and can have a service life of up to 75–100 years [4]. When effectively integrated into the national power grid, tidal energy can enhance long-term energy security.

Social Sustainability: Tidal energy development must be balanced with the rights and interests of fishermen, coastal communities, and local cultural practices. Community consultation and social impact assessments are essential components of any sustainable development process.

Establishing a clear and robust legal framework, aligned with international best practices, will serve as a critical foundation for Vietnam to effectively harness this resource in the future.

THE LEGAL FRAMEWORK FOR THE DEVELOPMENT OF TIDAL ENERGY IN VIETNAM

In recent years, Vietnam has implemented several policies to encourage the use of renewable energy sources in electricity production. The Constitution 2013 affirms the State's commitment to the development and utilization of renewable energy, stating: "The State encourages all activities for environmental protection, and the development and use of renewable energy" (Clause 1, Article 63). This provision constitutes the highest legal basis, setting forth the general orientation for the development of renewable energy sources, including tidal energy. In line with this constitutional directive, Vietnam has established a number of legal instruments regulating renewable electricity.



Tidal energy development contributes to boosting the maritime economy

The Law on Electricity 2024 addresses the development of renewable and new forms of electricity generation under Clause 14, Article 4. Besides, Article 23 of the same Law further stipulates the promotion of new energy electricity projects, authorizing the Government to introduce policies and mechanisms to incentivize such projects (including tidal energy projects) through, inter alia, exemptions or reductions of sea area usage fees and land use/lease fees.

Decree No.58/2025/ND-CP provides guidance on the implementation of certain provisions of the Law on Electricity 2024 with regard to renewable and new energy development. This Decree elaborates support mechanisms and preferential policies for new energy electricity projects. Specifically, for projects meeting relevant criteria, point (a), Clause 2, Article 6 stipulates: "Exemption from sea area usage fees during the basic construction period, not exceeding three years from the commencement date; 50% reduction of sea area usage fees for a subsequent nine-year period following the exemption term."

Decision No.500/QD-TTg approving the National Power Development Plan for the period 2021 - 2030, with a vision to 2050, outlines the strategic orientation for national electricity development: "To continue promoting the development of renewable, new, and clean energy sources, consistent with the safe operation capacity of the system and reasonable electricity generation costs, particularly self-produced and self-consumed electricity, and rooftop solar power." The plan sets the following targets: "Significantly increase the share of renewable energy in electricity production, reaching approximately 30.9% to 39.2% by 2030, with a long-term orientation toward a share of 67.5% to 71.5% by 2050."

However, Vietnam's legal system still reveals certain limitations regarding the development of tidal energy for electricity production:

Lack of a dedicated legal framework for tidal energy: Currently, regulatory provisions on new and renewable energy sources - including tidal energy are integrated within general legal instruments as mentioned above. There is no specific law or decree governing the development, management, operation, licensing, quality appraisal, technical standards, or environmental protection requirements specifically applicable to tidal energy projects.

Absence of targeted incentive policies for tidal energy projects: Incentive and support policies for renewable and new energy electricity projects are uniformly prescribed under Decree No. 58/2025/ND-CP. However, these policies are currently limited to exemptions or reductions of land and sea area usage fees, without any provisions for financial incentives such as capital subsidies, preferential electricity pricing, or support for energy export. This lack of tailored support has hindered research, investment, and the overall development of the tidal energy sector in Vietnam, preventing it from achieving its full potential.

INTERNATIONAL EXPERIENCE IN LEGAL FRAMEWORK ON TIDAL ENERGY

In the European Union (EU), placing development emphasis on tidal energy has been evidenced by a comprehensive framework of directives, which consistently address the various impact aspects of this issue. The EU has promulgated the Renewable Energy Directive (2009/28/EC) and the Maritime Spatial Planning Directive (2014/89/EU). In

addition, development efforts also take into account environmental impacts, which are regulated under the Environmental Impact Assessment (EIA) Directive (2014/52/EU) amending 2011/92/EU, the Strategic Environmental Assessment (SEA) Directive (2001/42/EC), and the Marine Strategy Framework Directive (2008/56/EC).

In particular, regarding the biological environment, the strategic development targeting toward tidal energy also should be aligned with the provisions set out in The Birds Directive (2009/147/EC), The Habitats Directive (92/43/EEC) and The Water Framework Directive (2000/60/EC). The EU has also issued several guidelines to support the implementation of these directives in the context of renewable energy development, aiming to ensure both objectives: environmental protection and the interests of relevant stakeholders.

In Canada, the effort on purpose of focusing on developing tidal energy has been supported by policy attention since 2012. In particular, Federally mandated marine spatial planning (MSP) has been underway for some time under the Oceans Act. Through the Oceans Act, nationwide MSP for five areas (Southern BC, Pacific North Coast, Newfoundland and Labrador Shelves, Estuary and Gulf of St. Lawrence, and Scotian Shelf and Bay of Fundy) is underway and is overseen by Fisheries and Oceans Canada (DFO).

Specifically, Nova Scotia is the most prominent center for tidal energy development, particularly with the Bay of Fundy. In 2015, the government here issued the Marine Renewable-energy Act, which includes provisions on licences and permits, distinguishes between experimental and commercial Marine Renewable-electricity Areas, and establishes requirements for environmental impact assessments and consultations with local communities. Notably, even before the introduction of this specific regulatory framework, the local government had already taken significant policy steps that laid the groundwork for the robust development of tidal energy, such as implementing policy on local Feed-in Tariff (FiT) and development of Statement of Best Practices,...

However, the regulation of MRE in Canada, has had at times, limited consistency between federal and provincial jurisdictions or what can be viewed as a disparate approach to regulation. The decision-making priority between agencies is not clear in terms of which agency should be leading processes and which agency or legislative instrument ultimately has the final say in project decisions. That is to say, agencies may wait for the decision of other relevant federal and provincial agencies before proceeding with issuing an authorization, approval, license, or permit. This is being addressed through several avenues.

In China, the issuance of Energy Law in early 2025 has marked a significant regulatory advancement in tidal energy in particular and renewable energy in general. This is a comprehensive piece of legislation designed to promote renewable energy development, enhance energy security, and advance the country's energy transition. Previously, the Renewable Energy Law of 2006 (supplemented and amended in 2009) governed various renewable energy sources such as wind, solar, biomass, and marine energy. At the same time, numerous marine energy policies and plans focused on research, technology development, and the implementation of pilot projects, laying the foundation for the growth of this green energy sector.

LESSONS LEARNED FOR THE LEGAL FRAMEWORK FOR TIDAL ENERGY DEVELOPMENT IN VIETNAM

Based on international best practices, several key legal mechanisms have proven effective in facilitating the development of tidal energy. These include the implementation of long-term, stable electricity pricing schemes to ensure capital cost recovery mechanisms and stimulate technological innovation; the establishment of dedicated bidding processes for tidal energy projects combined with tax incentives; and the promulgation of regulations concerning ecological restoration deposits, mandatory adaptive environmental impact assessments (EIA), and transparent disclosure requirements for operational data. Drawing from such experience, Vietnam can identify appropriate legal pathways tailored to its national context.

Firstly, it is imperative to establish a coherent and comprehensive legal framework specifically governing tidal energy. At present, Vietnam lacks sector-specific legal instruments regulating marine renewable energy, with tidal energy remaining particularly under-regulated. Existing provisions relevant to this sector are dispersed across various legislative texts, including the Law on Electricity, the Law on Marine and Island Resources and Environment, the Law on Environmental Protection, and the Maritime Code. This fragmented regulatory framework has resulted in regulatory inconsistencies concerning the licensing of surveys, pilot projects, and commercial deployment of tidal energy. Furthermore, there is currently no designated competent authority responsible for overseeing tidal energy development; no requirement for conducting Strategic Environmental Assessments (SEA) for tidal energy projects; no standardized framework for Power

Purchase Agreements (PPA); and no specific technical, environmental, or operational standards applicable to this sector.

In response, Vietnam should prioritise the deployment of pilot tidal energy projects in geographically suitable areas, accompanied by targeted investment in technical infrastructure and the establishment of independent monitoring authorities and technical survey bodies. The results of these pilot projects will provide an empirical and legal basis for developing regional testing facilities and for formulating a specialised legal framework governing marine renewable energy. Upon the establishment of such a framework, it is essential to incorporate marine energy development objectives into the broader National Marine Spatial Planning to minimise potential conflicts with marine conservation, fisheries, and other maritime sectors. In addition, legal instruments should be introduced to ensure the commercial bankability and long-term environmental and economic sustainability of large-scale tidal energy projects.

Secondly, Vietnam should consider implementing pilot support schemes for electricity pricing applicable to tidal energy projects in selected high-potential regions. Priority should be given to mechanisms such as Feed-in Tariffs (FiT) or Contracts for Difference (CfD), complemented by tax incentives, exemptions from water surface lease fees during initial project phases, and streamlined administrative procedures. Crucially, the legal framework governing these support mechanisms must be accompanied by binding environmental obligations, including mandatory adaptive environmental impact assessments, ecological restoration deposit requirements, and mandatory transparency measures regarding project operation and monitoring.

Thirdly, the licensing process should be streamlined and consolidated through the adoption of a single-window, inter-agency coordination mechanism involving all relevant ministries and regulatory bodies. This approach is consistent with international best practices and is intended to enhance regulatory efficiency, improve state oversight, and reduce legal uncertainties for investors throughout the project lifecycle, from preliminary surveys and assessments to final project approval and operational phases.

Finally, the legal framework for tidal energy development in Vietnam should incorporate mandatory provisions aimed at promoting human resource capacity and institutional expertise within the marine renewable energy sector. Priority should be given to establishing legal mechanisms that facilitate the training of technical specialists in marine energy technologies, environmental engineering, and maritime law, particularly through coastal higher education institutions. Furthermore, the law should encourage structured collaboration between universities, research institutes, and private sector entities, ensuring effective knowledge transfer and the development of technical competencies essential for supporting the long-term, sustainable, and legally compliant deployment of tidal energy projects■

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Strengthening basic investigation of marine and island resources and environment

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INTRODUCTION

Vietnam has a coastline of more than 3,260 km with a large sea area, rich in potential natural resources such as oil and gas, minerals, marine resources, seafood resources and marine tourism. Marine and island resources serve not only as a significant economic resources but also as a strategic foundation for the country's sustainable development. Basic investigation of marine and island resources and environment plays a pivotal role in assessing the current status and potential of these resources, while providing accurate scientific data to propose solutions for sustainable management, protection and exploitation. Additionally, it helps identify adverse impacts of socio-economic activities on the marine and island environment, thereby enabling the implementation of appropriate mitigation and prevention measures.

BASIC INVESTIGATION OF MARINE AND ISLAND RESOURCES AND ENVIRONMENT

A basic investigation of marine and island resources and environment refers to the systematic collection, analysis, and evaluation of data concerning marine and island resources and environment factors. Its purpose is to gain a comprehensive understanding of the current conditions, resource potential, and anthropogenic impacts on marine ecosystems, forming the basis for effective management and conservation policies. Fully awareness of the strategic position of the sea and islands for the economy, national defense and security, the Communist Party of Vietnam and the Socialist Republic of Vietnam have consistently introduced relevant policies and directives over the periods on basic investigation and management of marine and island resources and environment. On March 1st, 2006, the Prime Minister issued Decision No. 47/2006/QD-TTg on the approval of "the Master Project on the basic survey and management of marine natural resources and environment toward 2010, vision 2020". On February 9th, 2007, the 10th the Central Committee of Communist Party of Vietnam issued Resolution No. 09-NQ/TW on Vietnam's Marine Strategy to 2020, affirming that the potential of marine and coastal resources in national socio-economic development, environmental protection, and strengthening national security and defense. Between 2010 and 2013, the Government issued three additional decisions to expand projects under the Master Project. In particular, on June 25th, 2015, the National Assembly has just passed the Law on Natural Resources and Environment of Sea and Islands (Law No. 82/2015/QH13) and officially takes effect on July 1st, 2016. This marked a significant advancement in integrated and unified marine governance. Currently, the basic investigation of marine and island resources and environment is regulated by the Law on Natural Resources and Environment of Sea and Islands, along with decrees and circulars providing detailed guidance on the procedures and responsibilities in the investigation and management of marine and island resources and environment. Understanding the concepts and legal basis is an important foundation for effective investigation and contributing to the sustainable development of the country's marine and island resources.

Basic investigation of marine and island resources and environment is conducted through three keys stages: Data collection; data analysis and interpretation; and reporting with management and exploitation recommendations.

For data collection is the initial but extremely important stage, laying the foundation for the next stages. Remote sensing technology, Geographic Information System (GIS) and modern field survey methods are used to collect accurate data on topography, marine and island resources and environment. These data include not only information on natural conditions but also on exploitation activities, resource use and current environmental status.

Data analysisand interpretation is the process of transforming raw data into valuable information. Using specialized software, scientists and experts build models to assess environmental impacts and forecast changes in marine resources and environment. These analysis results help to better determine the distribution of resources, pollution status and factors affecting marine and island ecosystems.

Finally, reporting and proposing measures for resource management and exploitation is the concluding stage, based on the results of collection and analysis. The report will provide specific comments on the current status of marine resources and environment, and propose measures for sustainable

Seawater sampling using CTD-Rossetter device

management and exploitation. These measures include adjusting policies and laws related to resources and environment, to technical solutions to minimize negative impacts and optimize the use of marine and island resources.

Thus, the process of basic investigation of marine and island resources and environment is a series of closely linked stages, ensuring accuracy and science in data collection and analysis, as well as in providing reasonable measures for marine and island resource management and exploitation.

CURRENT STATUS OF MARINE INVESTIGATION EFFORTS

Recently, Vietnam has achieved substantial progress in marine resource and environment investigation, especially under "the Master Project on the basic survey and management of marine natural resources and environment toward 2010, vision 2020" (Decision No.47/2006/QD-TTg of the Prime Minister) and the Key Program for Baseline Survey of Marine and Island Resources and Environment to 2030 (Decision No. 28/QD-TTg, of the Prime Minister, dated January 7th, 2020). Up to now, notable milestones include the creation of 1: 200,000 scale nautical charts covering 819,500 km² (~82% of Vietnam's sea area), and marine geological-mineral surveys at a 1: 500,000 scale over 375,668 km² (~38% of Vietnam's sea area). And nevertheless, challenges persist-particularly in completing nautical charts, producing high-resolution bathymetric maps and completing seabed topography in strategically vital areas such as the Spratly and Paracel archipelagos and nearshore zones. Detailed depth data systems also require further development.

Marine geological-mineral surveys are carried out in many areas with different depths and conditions. However, in deep and offshore areas - where there is great mineral potential, the survey work still faces many difficulties due to the lack of modern equipment and complex survey conditions. In addition, the lack of specialized marine research vessels for deep and offshore areas leads to the need to hire and conversion ships to carry out projects. This process is not only costly but also slows down work progress, affecting the results of the survey. The above challenges show the need for further investment in facilities and equipment, as well as capacity building and closer coordination among relevant agencies to overcome difficulties in basic surveys of marine resources and environment.

Another major challenge in marine investigation is the shortage of highly qualified and experienced personnel in the field of marine science. In addition, the remuneration mechanism for those working at sea, especially working on off-shore areas, is still inadequate, making many people reluctant to participate in this field. Therefore, there is a need for specific policies to desirable employee benefit sand talent holding in the field of investigation on marine resource and environment.

THE APPLICATIONS OF SURVEY RESULT IN MARINE ECONOMIC MANAGEMENT AND DEVELOPMENT

Basic survey results provide foundational input for drafting marine-related legal documents such as the Law on Natural Resources and Environment of Sea and Islandsand associated regulations. They are particularly critical for the National Marine Spatial Planning (MSP), adopted by the National Assembly during its 15th, 7th session. This MSP guides rational, efficient, and sustainable resource use, biodiversity conservation, and protection of natural-cultural-historical values in Vietnam's seas and islands. The data also enhance the regulatory capacity of state agencies in monitoring and controlling marine resource utilization, ensuring legal compliance and adherence to international commitments on marine environmental protection.

Furthermore, the results of basic surveys on marine resources and environment have significantly contributed to elucidating the potential, comparative advantages, and functional characteristics of various marine spatial zones. These scientific results form a critical foundation for delineating marine spatial planning (MSP) and zoning schemes to support the sustainable development of key maritime economic sectors. These include the fisheries economy in conjunction with marine biodiversity conservation, as

well as the assurance of national defense and security, diplomatic relations, and international cooperation; maritime economy, maritime transport sector, seaport infrastructure development, shipbuilding and ship repair industries; and marine tourism and services sector. In parallel, such information enables investors to conduct informed decision-making processes based on reliable geospatial and environmental datasets, thereby mitigating investment risks and enhancing project efficiency.

Currently, research, surveys, and exploration of new marine energy sources such as such as methane hydrates, tides, ocean currents, waves, offshore wind power, and marine solar radiationare being accelerated, serving as a basis for developing new resources, These activities serve as a scientific and technological basis for the prospective exploitation and utilization of novel marine energy resources, in alignment with the strategic targets outlined in Resolution No. 36-NQ/TW on the Strategy for Sustainable Development of Vietnam's Sea-based Economy by 2030, vision to 2045.

In conclusion, basic investigations of marine and island resources and environmentare extremely important in marine economic development and management. These results provide detailed data on marine resources, environment and marine ecosystems, it's a scientific basis for managers and policy makers to make strategic decisions for management and development of the marine economy in a sustainable and effective manner, contributing to environmental protection and socio-economic development.

ORIENTATION AND DEVELOPMENT STRATEGY FOR SURVEY WORK

Basic investigations of marine and island resources and environment constitutes a critically important task, provides scientific and practical foundations for the formulation of planning, development strategies, policies, and legal frameworks. These efforts aim to ensure the sustainable management, exploitation, and utilization of marine and island resources and environments, as well as to enhance adaptive capacity in response to climate change.

In recent years, the Communist Party of Vietnam and the Socialist Republic of Vietnam have promulgated numerous resolutions, directives, and regulatory documents, while also deploying various measures to improve the effectiveness of basic investigations in the marine and island domain. Notably, the Government issued Resolution No. 48/NQ-CP dated April 3rd, 2023, approving "Strategy for sustainable exploitation and use of resources, environmental protection of seas and islands until 2030, vision to 2050". To effectively implement the objectives outlined in the Resolution, future basic survey activities require strategic orientation and specific development roadmaps, including: finalization and refinement of the legal and regulatory systems for the management, exploitation, and utilization of marine and island resources and the environment; formulation and synchronized implementation of incentive and support policies for the marine research and survey sector; strengthening and streamlining the institutional structure of state management agencies responsible for basic surveys; Increasing financial, human, and technical resources allocated to basic investigation works; proposing and launching high-priority programs, schemes, and projects with urgent relevance; enhancing inter-ministerial, inter-sectoral, and central-local coordination mechanisms; improving inspection, supervision, and evaluation of project implementation processes; advancing the application of modern technologies and innovative survey methodologies; promoting international cooperation and data sharing in the field of marine and island research.

CONCLUSION

In summary, basic investigations of marine and island resources and environment play a critically important role in providing accurate data and information essential for the effective management and protection of Vietnam's marine and island environment. These surveys serve as a foundational input for strategic decision-making processes, supporting marine planning and the sustainable development of the marine economy, while contributing to environmental protection, ecosystems and climate change adaptation. Over the years, basic survey efforts have achieved significant progress, including the systematic collection of comprehensive datasets and the delineation of critical marine zones requiring enhanced protection and regulatory oversight. However, several challenges remain-particularly in terms of limited resources, technological constraints, and insufficient inter-agency coordination-which have hindered the achievement of certain desired outcomes. To improve the quality, accuracy, and operational effectiveness of basic investigations, it is essential to intensify investments in advanced survey technologies and data processing systems. At the same time, emphasis should be placed on capacity building and professional development for technical personnel engaged in marine surveys. Establishing a robust and integrated coordination mechanism among relevant governmental agencies and organizations is also imperative to ensure the consistency, efficiency, and strategic alignment of all survey activities■

ORGANIC FARMING - solution for sustainable agricultural development

Organic farming stands as a beacon of sustainable agriculture, emphasizing natural processes and environmental stewardship. Organic farming methods have existed for a long time, before the appearance of inorganic farming methods. However, in the process of production development, the appearance of inorganic farming methods brings many immediate benefits such as: increasing productivity, reducing the labor of caring for crops and livestock... But in the long run, inorganic farming methods destroy the environment and production efficiency decreases due to polluted production environment, polluted agricultural products have a negative impact on human health... Therefore, organic farming methods have returned with the application of scientific and technological advances and mechanization in production, bringing high efficiency, providing safe products. This is a sustainable farming solution to protect human health, protect the environment and improve agricultural production efficiency.

Organic farming methods bring safe products

1. DEVELOPMENT OF ORGANIC AGRICULTURE

The organic agriculture sector is currently the fastest growing food sector. Growth rates in organic food sales have been in the range of 20-25 percent per year for over a decade. Globally, certified organic agriculture occupies less than 1 percent of lands and 1-2 percent of food sales. In some cases, the growth may reflect the entry of land long farmed organically into a certification programme rather than an actual switch in farming systems.

The recognition of the role of organic agriculture in achieving environmental objectives, including sustainable use of land set aside, led to the adoption of agri-environmental measures to encourage organic agriculture. Consumers concerned with food quality, as well as the protection of the environment, were the first to stimulate demand. New market opportunities have developed as part of a business strategy to address consumer concerns, particularly in the European Union and the United States. Major food companies see the processing, handling, stocking, and promoting of organic foods as part of a positive public image. Retailers of all sizes now aggressively promote and market organic food, with major food retailing chains now accounting for a major share of the retail markets for fresh as well as processed foods.

Consumers are increasingly sceptical on the safety of conventional foods and the soundness of industrial agriculture. The use of growth regulators stimulated interest in organic food. The crisis over dioxin-contaminated food and livestock diseases further increased demand for organic food. Consumer surveys in almost every country show a segment that demands an alternative to genetically modified foods. Governments have responded to these concerns by setting targets for the expansion of organic production. Thus, the concern of consumers and governments with the quality and safety of food has become the major driving force in the development of organic agriculture in industrialized countries. These concerns have also opened possible markets for developing country exporters, enabling them

to enhance foreign exchange earnings and diversify their exports. Price premiums of between 10-50 percent over prices for non-organic products, as well as more secure markets for organic commodities, can help counter-balance the loss of preferential trade arrangements, falling food prices and withdrawal of government support to agricultural inputs and other services. Major northern markets offer good prospects for suppliers of organic products not domestically produced. These include coffee, tea, cocoa, spices, sugar cane, tropical fruits and beverages, as well as fresh produce in the off-season. Increasingly, governments in developing countries are creating conditions in support of organic exports.

Non-certified organic agriculture is of particular importance for meeting local food requirements while providing protection and sustainable use of natural resources. Organic management makes it possible to save on production costs (especially important when cash is needed to purchase synthetic inputs) and to promote economic and/or food self-reliance. In market marginalized and resource-poor areas where farmers have no access to modern inputs and technologies, organic agriculture can also raise the productivity of traditional systems by optimizing the use of local resources.

2. CHALLENGES FACED BY ORGANIC FARMERS

Organic farming abstains from synthetic herbicides, making weed management a significant challenge. However, employing techniques such as mulching, cover cropping, and regular manual weeding proves effective in suppressing weeds.

Organic farming discourages the use of chemical pesticides, necessitating alternative pest management strategies. These include natural predators, insect-repelling companion plants, and the use of organic pest control methods like neem oil. The biggest harm of using chemical fertilizers and pesticides in agriculture is pollution of soil, water resources, air environment... Chemicals from fertilizers and pesticides seep into the soil, causing the soil to become hard, depleted of nutrients, leading to slow plant growth. Over time, toxic chemicals from inorganic fertilizers and pesticides seep into water sources, polluting rivers and lakes and affecting aquatic ecosystems. Chemical pesticides kill pests and also kill beneficial organisms such as beneficial insects, birds and other animals. The use of chemical fertilizers and pesticides in agriculture can lead to greenhouse gas emissions...

Maintaining optimal soil health without the use of synthetic fertilizers is paramount in organic farming. Regular application of compost, well-rotted manure, and cover cropping aids in enriching soil fertility and structure. Organic farming emphasizes biodiversity and crop rotation to minimize soil degradation and disease pressure. Planning a diverse crop rotation schedule is essential in this regard.

Connecting organic farmers with consumers who value and support their produce can be challenging. This necessitates robust marketing strategies, partnerships with local markets, and educating consumers on the benefits of organic produce.

3. SOLUTIONS TO OVERCOME CHALLENGES

Organic farming methods apply farming measures such as: using organic fertilizers, crop rotation and intercropping, deep plowing, using biological control measures... This method applies to both crop and livestock farming. In farming, organic farming methods instead of using chemical fertilizers use manure, fertilizers made from plants to provide nutrients for plants and improve soil fertility. Combined with deep plowing helps improve soil structure, making the soil loose, rich in nutrients, easily retaining water and organic matter for the soil, protecting long-term fertility.

Use natural pest control measures such as natural enemies, biological products or herbal pesticides, do not use pesticides made from toxic chemicals. Organic fertilizers and biological control measures do not harm the soil and water sources. In animal husbandry, the organic farming method is not to use foods containing growth stimulants, lean meat additives...

Organic farming helps maintain and enhance biodiversity by minimizing the use of chemical pesticides. The use of biological control measures such as natural enemies or natural pesticides not only helps protect the environment but also maintains ecological balance in agriculture. Rotating and intercropping crops helps prevent soil nutrient depletion and minimizes the development of pests and diseases, increasing biodiversity.

Implementing organic farming methods protects the production environment and ecological environment well, such as: increasing soil porosity and humus, reducing soil and water pollution, protecting biodiversity, reducing greenhouse gas emissions, protecting soil and preventing erosion...

At the same time, the application of crop rotation and intercropping helps create a more diverse environment for beneficial animals and insects, thereby creating natural resistance for crops, thereby minimizing pests. Cover crops, use of organic fertilizers and sustainable farming help maintain

soil porosity and limit erosion, especially in mountainous areas, helping to protect the soil for long-term cultivation.

Propagating and mobilizing farmers to change their farming methods through agricultural extension channels and mass media has a wide influence, thereby accelerating the process of changing farmers' farming methods. By building on local knowledge, organic agriculture approaches revitalize traditional customs and local self-reliance. Employment opportunities and higher returns on labour encourage people to remain in agriculture, reinvigorating rural communities. Strengthened social cohesion and partnerships within the organic community make for better connections with external institutions. Organized groups, such as producer cooperatives, have better access to markets and can negotiate their needs as equal partners in the food supply chain.

Together with the production system, the social environment of those engaged in organic agriculture generally improves: in fact, many organic systems incorporate fair trade principles which improve working conditions. The IFOAM Basic Standards includes a chapter on Social Justice Standards. These refer to and are based upon the conventions of the International Labour Organisation on labour welfare and to the human rights charters of the United Nations.

A growing number of certified organic agriculture commodities produced by small-scale farmers organized in democratic cooperatives meet fair trade requirements: farmers are paid adequately to cover costs of production and a social premium to improve the quality

Consumers are increasingly sceptical on the safety of conventional foods

of life. Although the organic movement shares a consensus that social requirements are necessary, specific standards are controversial. Standard-setting bodies are sensitive to national sovereignty and the cultural context governing social and economic relations. Such standards might create trade barriers to some developing countries organic exports, but this pressure may trigger social and economic reform in many countries. When farmers widely apply organic farming methods, they create safety in production, protect land and water resources, and create a cleaner and more sustainable agriculture.

Switching to organic farming methods that apply scientific and technical measures in agricultural production is a farming solution that brings many economic benefits, is environmentally friendly and protects human health.

Implementing Integrated Pest Management (IPM) combines various strategies like biological control, cultural practices, and natural enemies of pests. This approach minimizes the impact of pests while preserving the ecological balance. Embracing regenerative practices like no-till farming, agroforestry, and incorporating perennial crops can significantly enhance soil health and long-term sustainability.

Exploring various market channels, including farmers' markets, community-supported agriculture (CSA), and online platforms, can help expand the reach and accessibility of organic produce.

Offering training and workshops to farmers on organic farming techniques, soil health management, and sustainable practices ensures a knowledgeable and empowered farming community.

While organic farming presents its own unique challenges, the benefits far outweigh the hurdles. By adopting innovative techniques, leveraging the power of regenerative agriculture, and fostering strong community connections, organic farmers can not only overcome these challenges but also thrive in their commitment to sustainable and environmentally conscious farming practices■

XUÂN THẮNG -
Source: https://www.fao.org

VIETNAM'S REDD+ SAFEGUARDS INFORMATION SYSTEM: Current status and the need for updating/ improvement

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1. INTRODUCTION

Reducing greenhouse-gas (GHG) emissions by limiting forest loss and degradation, conserving and enhancing carbon stocks, and managing forest resources sustainably (REDD+) was established under the United Nations Framework Convention on Climate Change (UNFCCC) as an international financial mechanism that provides results-based payments to developing countries for successfully implementing REDD+ actions. In addition to climate-change mitigation and carbon-related benefits, not only REDD+ can deliver a range of non-carbon (co-benefit) outcomes; butit also entails potential environmental and social risks. Recognizing these risks, UNFCCC Parties adopted set of seven REDD+ safeguards principles at COP 16, commonly called the "Cancun safeguards." The Cancun Agreement requests countries implementing REDD+ to "address" and "compliance" these seven safeguards, which cover governance, emission-reduction risks, social and environmental benefits.

Vietnam is recognized as a pioneer country in REDD+, and has prepared for REDD+ implementation by issuing the National REDD+ Program, developing the National Forest Monitoring System (NFMS), Forest Reference Emission Levels/Forest Reference Levels (FREL/FRL), and developing and operating an online Safeguard Information System (SIS). Therefore, Vietnam is eligible to receive payments based on REDD+ results. Developing a Safeguard Information System (SIS) is one of the three important safeguard requirements in REDD+ of the UNFCCC. SIS is a national-level system that provides information on "review" and "compliance" with the Cancun Safeguard Principles during REDD+ implementation in Vietnam. Information on "review" of the Safeguard Principles includes descriptive information on relevant policies, laws and regulations. Information on "compliance" with the safeguards principles includes descriptive information and data on the actual implementation of policies, laws and regulations and results related to the implementation of REDD+. In order to further improve the SIS system and meet the requirements of REDD+ standards, this article assesses the current status of available information and data, identifies gaps and makes suggestions for maintaining and continuously updating the SIS system in the context of digital transformation to serve REDD+ results-based payment programs and projects in Vietnam, meeting the requirements of the UNFCCC.

2. CURRENT STATUS OF INFORMATION AND DATA ON REDD+ SAFETY INFORMATION SYSTEM

The process of developing the SIS for Vietnam began in late 2015, with the coordination of the Office of the National REDD+ Steering Committee, mobilizing resources in the design and operation of the SIS. In 2018, the basic information structure of the Vietnam SIS was built, many relevant information fields were collected and posted on the online system, although not all necessary information was available at that time because the National REDD+ ActionProgram (NRAP) [5] had not been widely implemented, or some safeguards' indicators had not been fully defined.

The Vietnam REDD+ SIS information page is built with a layout including information fields: Home page, overview, principles, library, feedback and contact on both English and Vietnamese language platforms. By design, the SIS system will collect data from different sources, including: National Forest Management Information System (FORMIS), Forest Resources Monitoring System (FRMS), REDD+ Portal, General Statistics Office (GSO), Ministry of Ethnic Minorities and Religions (CEMA), Ministry of Agriculture and Environment (MAE), databases of other ministries and sectors; REDD+ implementation reports and other sources. The main information sources currently available in the SIS include data on reports from relevant agencies and organizations; appraisal/monitoring reports from REDD+ projects/programs (such as the FCPF-ERP Program); FRMS; GSO; CEMA…) is widely publicized to meet the requirements for implementing payments based on GHG emission reduction results from REDD+ programs and projects.

Information updates on the SIS will be carried out annually or every 6 months, depending on the specific data source. In Vietnam, information and data updates on the SIS system have started in 2022

Table 1. Assessment of the suitability of safeguards' indicators according to TREE Standards

Principle	Topic	Index		
A	1.1. Consistent with the national forestry program	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	1.2. Consistent with relevant international conventions and agreements	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
B	2.1. Respect, protect and implement the right to access information	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	2.2. Promoting transparency and preventing corruption	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	2.3. Respect, protect and implement land use rights	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	2.4. Respect, protect and implement the right to access justice	Structure (Matched)	Process (Partially Matched)	Result (Not suitable)
C	3.1. Identify ethnic minorities and local communities	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	3.2. Respect and protect traditional knowledge	Structure (Matched)	Process (Partially Matched)	Result (Not suitable)
	3.3. Respect, protect and implement the rights of ethnic minorities and local communities	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
D	4.1. Stakeholder engagement	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	4.2. Participation of ethnic minorities and local communities	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
E	5.1. No conversion of natural forests	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	5.2. Protection of natural forests and biodiversity and ecosystem services	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
	5.3. Enhance social and environmental benefits	Structure (Matched)	Process (Partially Matched)	Results (Partially Matched)
F	6.1. Reverse risk treatment action	--	Process (Partially Matched)	--
G	7.1. Actions to reduce emissions displacement	--	Process (Partially Matched)	--

(Source: [6])

by assessing new REDD+ initiatives/programs and collecting newly updated data. From 2023, Vietnam's SIS system will continue to be updated to ensure that the structure of indicators, content and data are revised and updated in accordance with the requirements of the REDD+ Trading Platform (ART) and the REDD+ Environmental Excellence Standard (TREE), details are presented in Table 1.

Accordingly, the information and data of the SIS system mainly describe in detail the 7 principles of the Cancun safeguards with 17 topics and 121 indicators/ criteria related to the review and compliance with Vietnam's REDD+ safeguards requirements. Analysis based on 44 indicators (including 14 structural indicators, 16 process indicators and 14 outcome indicators according to the TREES standard) shows that the current structural indicators are completely consistent with the standard. The system has fully described the policies, laws and regulations related to the 7 Cancun safeguards principles. For the 16 process indicators, only 2 indicators are suitable: Respect, protect and implement the right to access information and do not convert natural forests. The remaining 14 process indicators are currently only partially suitable, due to the lack of implementation guidelines as well as the organization and coordination of implementation.

Vietnam has a forest cover rate of nearly 42%

The current results indicators are mostly only partially consistent, especially the two indicators on respecting, protecting and implementing the right to access justice; Respecting and protecting traditional knowledge are not consistent with the standard requirements. The analysis results also show that currently, regarding ensuring access to justice, there are adequate policies, laws and regulations supporting access to justice; feedback mechanisms, conflict resolution, and complaints applied in REDD+. However, the results of the feedback mechanism, conflict resolution, and complaints applied to REDD+ are not currently available on the SIS system. Regarding respecting and protecting traditional knowledge, information and data are fully displayed on the SIS system such as: Policies, laws and regulations on the rights of ethnic minorities and local communities; Benefits, risks and measures to promote the rights of ethnic minorities and local communities; The results relate to the rights of ethnic minorities and local communities to land and forests and the access to forest resources of ethnic minorities and local communities. However, there is currently a lack of indicators in the system such as: the results of solutions in the National REDD+ Program to enhance benefits and reduce risks for ethnic minorities and local communities; results related to benefit sharing for ethnic minorities and local communities; results related to cultural rights and results of the feedback, conflict resolution and grievance mechanism (GRM) for REDD+.

In addition, there are many other indicators that do not have data yet such as: Funding for the national REDD+ program; results related to REDD+ benefit sharing for ethnic minorities and local communities; implementation of stakeholder participation mechanisms at the national and local levels; results of implementing solutions on natural forest and biodiversity conservation; results of identified solutions to conserve natural forests and biodiversity; number of species used in plantation forests; results of solutions to reduce the risk of emission reversal in the National REDD+ Program and results of specific solutions to reduce emission displacement.

The results of the assessment of the data connection of indicators between the SIS system and database sources related to forest resource management results such as the Forestry Management Information System (FORMIS), the Forest and Forest Land Monitoring System (FRMS), the Vietnam REDD+ information page... have been interrupted, disconnected, or switched from open access to account authorization due to the process of restructuring the apparatus and new regulations on data information sharing. This is considered a risk of the SIS system when many indicators are directly connected to other data information systems.

3. CONCLUSION AND RECOMMENDATIONS

3.1. Conclusion

The Vietnam REDD+ safeguards information system has compiled data information based on 7 REDD+

safeguards principles, detailed into 17 topics, each topic requires answering questions related to REDD+ actions, information and data must demonstrate the requirements for review and compliance with safeguards principles, specific indicators will demonstrate information and data review and compliance. This system must be maintained regularly and requires updating information and data annually or every 6 months. However, the results of the assessment of the current status of information and data on the implementation of 121 safeguards indicators on the SIS system show that although the current indicators and review indicators have not been updated regularly, the information and data are quite complete.

For the group of compliance (result) indicators, there is still a lack of information and data, as some indicators require periodic assessment, and the capacity to integrate information and data from other monitoring and evaluation indicator systems is still limited. According to Vietnam's REDD+ implementation roadmap, the country has now entered the full implementation phase, which requires the nation to comply with safeguard measures, and the information and data on the result indicators must be updated to the SIS system in both Vietnamese and English versions. To obtain information that ensures compliance with Vietnam's REDD+ safeguard principles, especially the result indicators on the implementation of REDD+ policies and measures, it is necessary to mobilize resources and time to compile and update them from various sources.

3.2. Recommendations

Vietnam is considered a country with a high level of participation in the REDD+ financial mechanism, currently implementing the FCPF-ERP program in the North Central region and in the process of negotiating to deploy the LEAF Program in the South Central and Central Highlands regions. Forest carbon standards require increasingly high levels of payment and exchange at higher prices. For example, the FCPF program pays an average of 5 USD/ton CO_2, however, the LEAF Program requires a minimum of 10 USD/ton CO_2 for the results-based payment mechanism, and if carbon credit transactions are conducted, the price may be higher due to different standards and conditions. High carbon standards come with high compliance with safeguards principles and require higher implementation resources. Currently, forest carbon pricing in Vietnam has not been fully calculated as a basis for payment and exchange of forest carbon credits. Therefore, it is recommended that is need of research and development of guidelines for forest carbon pricing according to different forest carbon standards, because each carbon standard will have different requirements for compliance with the Forest Carbon Standards, and accordingly, the costs for ensuring compliance will also be different.

Along with that, to ensure information and data requirements, it is necessary to innovate in the application of information technology, large databases, and artificial intelligence to serve the SIS system to connect database systems of indicators, review indicators and comply with safeguards principles, establish an online safeguards index update system... to improve transparency and accountability, and especially to serve forest carbon standards, or payment mechanisms based on REDD+ results■

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Current status of financial mobilization and utilization for special-use forest development in Vietnam

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Special-use forests (SUFs) are forests with special value in nature conservation, scientific research, protection and environmental protection. According to Clause 2, Article 5 of the Forestry Law 2017, special-use forests are forests used mainly to conserve natural forest ecosystems, forest biological gene sources, scientific research, conservation of historical - cultural relics, beliefs, scenic spots combined with ecotourism; recreation, entertainment except for strictly protected areas of special-use forests; provision of forest environmental services (FES) including: National parks (NPs); Nature reserves; Species - habitat conservation areas; Landscape protection areas including forests preserving historical - cultural relics, scenic spots; religious forests; forests protecting the environment of urban areas, industrial parks, export processing zones, economic zones, high-tech zones; Research and scientific experiment forests; national botanical gardens; national seed forests [2]. Currently, the SUFs system is established in 54 of 63 provinces and centrally-run cities with a total area of 2,303,961 ha (forested area is 2,195,725 ha, including 2,100,785 ha of natural forest and 94,940 ha of planted forest); of which, the area of national parks is 1,168,571.68 ha, nature reserves are 1,026,334.27 ha, species and habitat conservation areas are 69,383.84 ha, landscape, historical and environmental protection areas are 198,231.71 ha and scientific experimental research forests are 10,441.82 ha [9]. The financial mechanism for SUFs development is very diverse and rich; Depending on the ability to balance the budget, the actual conditions of each locality as well as the capacity to mobilize, receive, manage and use effectively of each Management Board (MB), it usually includes 4 basic contents: Mobilizing and creating financial resources; Allocating and using financial resources; Managing financial resources; Checking and controlling finances. In which, mobilizing, creating financial resources and allocating and using financial resources (such as revenue and expenditure) play a key role.

1. REVENUE FOR SPECIAL-USE FORESTS' DEVELOPMENT

Regarding revenue sources for the development of special-use forests, the the Law on Forestry 2017 clearly states that the State ensures resources for the management, protection and development of special-use forests and protective forests (Article 4) and stipulates that financial sources in forestry include: State budget; Investment, contributions, support and sponsorship from domestic and foreign organizations and individuals; Revenue from forest product exploitation; forest and forest land leasing; Revenue from the obligation to pay for replacement forest planting due to the conversion of forest use purposes to other purposes; Revenue from forest environmental services (FES) and forest environment leasing; Credit capital from domestic and foreign financial institutions; Other financial sources as prescribed by law (Article 92) [2]. Article 87 of Decree No. 156/2018/ND-CP dated November 16, 2018 detailing the implementation of a number of articles of the Forestry Law also stipulates: "The State ensures the investment budget for activities to protect and develop special-use forests..." [3].

Regarding revenue from the State budget, on July 12, 2022, the Prime Minister issued Decision No. 809/QD-TTg approving the Sustainable Forestry Development Program for the 2021-2025 period, with a total estimated capital for the Program of VND 78,585 billion, of which: State budget: VND 13,682 billion; other legal capital sources: VND 64,903 billion. The result of mobilizing funds to implement the Program in 2021-2022 is about VND 30,330 billion, an average of VND 15,165 billion/year, of which: State budget is about VND 4,006 billion, an average of VND 2,003 billion/year, accounting for 13.2%; Other sources are about 26,324 billion VND (of which: DVMTR: 6,856 billion VND; other legally mobilized capital: 19,468 billion VND) accounting for 86.8%; average 13,162 billion VND/year [7].

Regarding promoting socialization in mobilizing investment resources for the protection and

Table 1. Average revenue structure of a SUFs' Management Board

No.	Revenue	2018		2019		Synthetic	
		Value (million VND)	Structure (%)	Value (million VND)	Structure (%)	Value (million VND)	Structure (%)
1	Regular expenses	5.236	31,46	5.366	27,4	10.602	29,26
2	Central development investment	404	2,42	285	1,46	689	1,90
3	Local development investment	907	5,45	1.217	6,21	2.124	5,86
4	Forest protection policy (Decision No. 24/2012/QD-TTg)	753	4,52	693	3,54	1.445	3,99
5	Sustainable Forestry Program	1.208	7,26	1.434	7,32	2.642	7,29
6	National Breeding Program	46	0,46	90	0,46	116	0,46
7	Science and technology topics	425	2,55	460	2,35	885	2,44
8	Other programs	1.514	9,1	982	5,01	2.496	6,89
9	Retained revenue	2.860	17,18	3.373	17,22	6.233	17,20
10	PFES	2.764	16,61	3.247	16,58	6.011	16,59
11	Other	499	3	2440	12,46	2.939	8,11
Total		**16.646**	**100**	**19.587**	**100**	**36.233**	**100**

(Source: [5])

development of special-use forests, it is reflected in the Law on Forestry 2017 and Decree No. 156/2018/ND-CP dated November 16, 2018 of the Government. Specifically, Clause 4, Article 53 of the Law on Forestry 2017 stipulates that: "Forest owners shall organize, cooperate, associate or lease forest environments to organizations and individuals for ecotourism, resort and entertainment business in special-use forests, ensuring that they do not affect the conservation of natural ecosystems, biodiversity, environmental landscapes and other functions of the forest". From Article 61 to Article 65 of the Law on Forestry, regulations on Payment for Forest Environmental Services (PFES) are specified, including five types of services and seven groups of payers. The five types of PFES include soil protection, prevention of erosion, and reduction of sedimentation in reservoirs, rivers, and streams; Regulating and maintaining water resources for production and social life; Absorbing and storing carbon from forests; reducing greenhouse gas emissions from limiting deforestation and forest degradation, sustainable forest management, green growth; Protecting and maintaining the beauty of natural landscapes, conserving biodiversity of forest ecosystems for tourism business; Providing spawning grounds, food sources, natural breeds, water sources from forests and environmental factors, forest ecosystems for aquaculture. Seven groups of payers who must pay for forest environmental services include: Hydropower production facilities must pay for services on land protection, limiting erosion and sedimentation of lakes, rivers, streams, regulating and maintaining water sources for hydropower production; Clean water production and supply facilities must pay for services on regulating and maintaining water sources for clean water production; Industrial production facilities must pay for services on regulating and maintaining water sources for industrial production; Organizations and individuals doing business in ecotourism, resorts and entertainment services must pay for services related to protecting and maintaining the beauty of natural landscapes and conserving biodiversity of forest ecosystems; Organizations and individuals engaged in production and business activities that cause large greenhouse gas emissions must pay for services related to absorbing and storing carbon in forests; Aquaculture facilities must pay for services related to providing spawning grounds, food sources, natural breeds, water sources and environmental factors, forest ecosystems for aquaculture; And other group of payers as prescribed by law [2]. In addition, in order to mobilize financial resources from global climate finance initiatives, on December 28, 2022, the Ministry of Agriculture and

Table 2. Average expenditure structure of a RDDD Management Board

STT	Revenue	2018		2019		Synthetic	
		Value (million VND)	Structure (%)	Value (million VND)	Structure (%)	Value (million VND)	Structure (%)
1	Staff salaries	5.005	29,53	5.173	28,36	10.178	28,92
2	Machine operation cost	2.117	12,49	2.123	11,64	4.241	12,05
3	Forest development expenditure	541	3,19	549	3,01	1.091	3,10
4	Expenditures for performing professional tasks related to sustainable forest management	2.210	13,04	2.341	12,83	4.551	12,93
5	Construction and equipment investment costs	1.895	11,18	3.033	16,63	4.928	14,00
6	Conservation and scientific research expenses	356	2,1	253	1,39	609	1,73
7	Buffer zone community support	491	2,9	487	2,67	978	2,78
8	For wildlife rescue operations	34	0,2	17	0,09	51	0,14
9	Biodiversity survey expenditure	94	0,55	46	0,25	140	0,40
10	Fixed asset depreciation	358	2,11	507	2,78	865	2,46
11	Allocation to the public service unit's fund	2.772	16,36	2.725	14,94	5.497	15,62
12	Forest inventory and monitoring	56.9	0,34	55	0,3	112	0,32
13	Other expenses	1.018	6,01	932	5,11	1.950	5,54
Total		**16.947**	**100**	**18.242**	**100**	**35.189**	**100**

(Source: [5])

Rural Development submitted to the Government for promulgating the Decree No. 107/2022/ND-CP on piloting the transfer of emission reduction results and financial management of greenhouse gas emission reduction payment agreements in the North Central region. Thanks to that, forest owners in the North Central region in general and the Specialized Forest Management Boards in this region in particular have more opportunities to receive financial resources from the transfer of emission reduction results [8] (Table 1).

According to the Study on evaluating investment policies for sustainable development of special-use forests in Vietnam, jointly conducted by the German International Cooperation Agency (GIZ) and the General Department of Forestry, the results of the survey of 51 special-use forest management boards showed that the average revenue of a special-use forest management board in 2019 was 19.6 billion VND, higher than 16.6 billion VND in 2018; The average revenue structure for a special-use forest management board focuses on 3 main sources: Regular expenditure (29.26%), retained fees (17.02%) and sources from forest environmental service payments (16.59%), while revenue from target programs is insignificant (such as the National Seed Program accounting for 0.46%).

Thus, in terms of revenue for special-use forest development, financial sources are mobilized in a variety of ways but are not balanced, depending heavily on the State budget. Regarding resource creation, the Management Boards have developed ecotourism business activities, developed forest environmental services... however, the level of development is different and uneven among the Special Reserve Management Boards.

2. SOURCES OF FUNDING FOR SPECIAL-USE FOREST DEVELOPMENT

The cost of developing special-use forests includes many items, mainly focusing on forest management and protection, investment in buffer zone communities and other costs. The average support level for forest management and protection is 100,000 VND/ha/year. Buffer zone communities are supported with an average of 50 million VND/community/year to develop their livelihoods [11]. In addition, there are other costs such as costs for preparing forest protection records; costs for forest protection inspection and acceptance;

costs for investment in works and equipment; costs for conservation and scientific research; costs for wildlife rescue activities, etc (Table 2).

An analysis of the average expenditure structure of a Special-Use Forest Management Board in 2018 and 2019, based on the above-mentioned survey by GIZ and the Vietnam General Department of Forestry, shows that the highest proportion of spending was on staff salaries (28.92%), followed by appropriations to the fund of the public service unit (15.62%), a portion of which was later mostly allocated to additional salary payments. Investment in infrastructure and equipment accounted for 14%, administrative operation costs for 12.05%, and expenditures on professional tasks related to forest protection and management for 12.93%. Expenditures with lower proportions included biodiversity conservation and scientific research (1.73%), wildlife rescue activities (0.14%), and forest resource monitoring (0.32%), despite the high demand for budget in these areas. Moreover, spending on biodiversity surveys - a pressing and essential task for nature and biodiversity conservation, environmental protection, sustainable use of natural resources, and national sustainable development, was also very limited, accounting for only 0.4% over the two years of 2018 and 2019. Thus, the current developing special-use forests' expenditures are mainly focused on administrative operations and forest protection management activities.

3. PROPOSING SOLUTIONS TO PERFECT SUSTAINABLE FINANCIAL MECHANISMS FOR SPECIAL-USE FOREST SYSTEMS

In recent times, the Government's SUF development goals have been basically achieved. However, in the context of increasing pressure on livelihoods, limited resources, and the ongoing degradation of forest resources and biodiversity, SUF Management Boards are facing many difficulties and challenges such as limited state budget for professional activities; difficulty in mobilizing and attracting non-state budget investment sources, especially investment sources from the private sector. In particular, the implementation of the financial autonomy mechanism still has many obstacles, and there are still other barriers, difficulties and challenges related to institutions, policies, quality of human resources, infrastructure conditions, etc… These factors limit the assignment of tasks, signing of results-based contracts. Thereby hindering improvements in financial efficiency and the generation of income to reinvest in conservation activities and to enhance the income of officers, staff, and workers at Special-Use Forest Management Boards [4]. Therefore, achieving financial sustainability for SUF areas is critically important.

Financial sustainability for special-use forests reflects the ability to ensure adequate, stable, long-term financial resources and the ability to allocate them in a timely manner in an appropriate form, to cover all costs for special-use forests. At the same time, it ensures that special-use forests are managed practically and effectively, meeting conservation and other objectives. To ensure the synchronous and effective implementation of sustainable financial mechanisms for the special-use forest system in Vietnam, the author recommends the following recommendations:

First, perfecting sustainable financial mechanisms and policies

Currently, the financial mechanism for the SUF system is implemented according to the Law on Forestry 2017, regulations and detailed instructions for the implementation of the Forestry Law; regulations of specialized laws such as: Law on Biodiversity, Law on Environmental Protection, Law on Cultural Heritage, Law on Handling of Administrative Violations and a number of other relevant laws. After the Forestry Law was passed by the National Assembly, the Ministry of Agriculture and Rural Development submitted to the Government for promulgation Decree No. 156/2018/ND-CP detailing the implementation of a number of articles of the Forestry Law, including many important chapters and articles regulating SUF; reflecting contents such as: Regulations on management of 3 types of forests, payment for forest environmental services, forest fire prevention and fighting, investment and development policies for SUF [3]. It can be affirmed that the Law on Forestry 2017 and its guiding documents are new step forward in the process of institutionalizing major policies and guidelines of the Party and State. The current regulations in forestry law not only focus on forest protection but also cover and ensure that forestry activities are based on the value chain, from forest protection, forest development, forest use, production organization, processing and trade of forest products. Notably, the current regulations have created a legal corridor to encourage the Management Boards of Special-use Forests not only to carry out the tasks of forest protection, biodiversity conservation of forest ecosystems but also to take advantage of opportunities to exploit and mobilize financial resources outside the budget through ecotourism activities, payment for forest environmental services, science and technology and international cooperation.

The wildlife rescue

However, it is essential to revise and supplement regulations on forestry development investment policies and PFES policies in a way that expands existing PFES revenue sources. It is also necessary to promote and create favorable conditions, as well as mechanisms and policies, to implement agreements on the transfer of emission reduction outcomes between partners and localities; to pilot, review, and scale up policies on payments for forest carbon sequestration services. In addition, it is necessary to develop technical and economic norms as a basis for the State to assign tasks, place orders, or organize bidding for the provision of public products and services. In particular, urgent efforts are needed to develop and issue technical and economic norms for: (i) forest protection, inventory, and monitoring; (ii) rescue, rehabilitation, and release of wild animals; (iii) forest biodiversity monitoring; and (iv) collection, processing, and preservation of forest biological specimens.

Second, promote socialization and attract investment from the private sector.

Assessing the status of forest management and development up to 2017, Directive No. 13-CT/TW dated January 12, 2017, of the Party Central Secretariat on strengthening the Party's leadership in forest management, protection, and development concluded that: "Forest management, protection and development remain limited and weak; planning for forest protection and development is not synchronized with land use planning and socio-economic development planning; forest areas loss due to wildfires and landslides is increasing; afforestation and reforestation efforts are behind schedule; the socialization of forest management, protection, and development remains limited; while forest cover has increased, it is difficult to achieve the targets set in the 12th National Party Congress Resolution…" [12]. This shows that the Party and the State have comprehensively reviewed and analyzed the constraints in forest management and development, in which the socialization of forest management, protection, and development is identified as an important factor, yet has not been effectively promoted.

To specify the content of socialization of forest management, protection and development from Directive No. 13-CT/TW of the Central Secretariat, on April 1, 2023, the Prime Minister issued Decision No. 523/QD-TTg, which identified "Research and development of policies to promote the socialization of forestry, attract investment in forestry, natural forest management, community forestry development, and forest environmental services" as one of the important policy solutions [6]. Currently, the socialization of forest planting and forest restoration is increasingly receiving attention and response from people, businesses and organizations, contributing to the sustainable development of the country. Over the past years, the State has encouraged economic sectors to participate in

forest development, through many important policies such as land allocation and forest allocation, specific policies to encourage investment, develop cooperation, link production, support preferential loans, etc… Since then, it has mobilized all resources and diversified capital sources for implementation, of which capital from the state budget accounts for about 17%, the remaining 83% is socialized capital from investment mobilization, contributions, and support from organizations, businesses, and individuals. In addition, the formation and effective organization of the Forest Protection and Development Fund system from the central to local levels is also a typical success of the forestry sector in effectively and sustainably mobilizing social resources for forest management, protection, and development. Revenue sources for forest environmental services will continue to be expanded in the coming time, first of all, forest carbon services and forest carbon credit trading. In the coming time, to promote socialization and attract investment from the private sector, it is necessary to improve the investment and business environment, reform administrative procedures to promote the leasing of forest environments, organize cooperation and linkage between forest owners and businesses, research institutes, schools and training facilities in scientific research and teaching activities, etc.

Third, promote access to new financial initiatives

Payments for ecosystem services are receiving increasing attention and promotion from the international community as one of the effective and sustainable financial mechanisms for forest protection, reducing deforestation and forest degradation. In addition, markets for the purchase, sale, transfer, and exchange of emission reduction results, forest carbon credit trading, and result-based payments under the REDD+ mechanism have shown positive signs. Currently, several international organizations, corporations, and foreign enterprises are expressing interest and promoting cooperation with the Ministry of Agriculture and Rural Development (MARD) in developing projects and agreements for forest carbon emission reduction result transfers, such as the Emergent Forest Finance Accelerator and the German Agency for International Cooperation (GIZ), among others.

However, to effectively access these new financial initiatives, it is necessary to strengthen the organization of policy dialogue forums, conferences, workshops, and training courses to build capacity for implementing new financial themes, mechanisms, and initiatives. Active participation in knowledge-sharing networks at the regional, national, and international levels is also essential for exchanging experiences and staying updated■

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THE RISE OF PLASTIC POLLUTION: Cause, Consequences and Solutions

Plastic pollution is the accumulation of plastic in the environment, causing harm to ecosystems, wildlife, and human health. It's a global problem with a wide range of sources and impacts. Every day, the equivalent of 2,000 garbage trucks full of plastic are dumped into the world's oceans, rivers, and lakes. Every year 19 – 23 million tonnes of plastic waste leaks into aquatic ecosystems, polluting lakes, rivers and seas. Plastic pollution can alter habitats and natural processes, reducing ecosystems' ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social well-being. Plastics bring undeniable benefits from energy savings to material conservation. Yet, the growing crisis of plastic pollution threatens both planetary and human well-being. For decades, plastic pollution has infiltrated every corner of the world contaminating the water we drink, the food we eat, and the air we breathe. Microplastics are now even found in our bodies. This World Environment Day, we are mobilizing communities across the globe to implement and advocate for lasting solutions to plastic pollution.

IMPACTS OF PLASTIC POLLUTION

Plastic pollution has become ubiquitous in natural and built environments, raising concerns about potential harm to humans and nature alike. Once in the environment, plastic pollution is persistent and may take between 100 to 1,000 years or more to decompose, depending on environmental conditions. Once in the environment, plastic pollution can fragment into smaller pieces of plastic. Microplastics are plastic particles ranging in size from five millimeters to one nanometer; nanoplastics are plastic particles smaller than one micrometer. Both are found in every ecosystem on the planet from the Antarctic tundra to tropical coral reefs. Plastic pollution affects all land, freshwater, and marine ecosystems. It is a major driver of biodiversity loss and ecosystem degradation and contributes to climate change.

As plastic pollution is a transboundary issue, a global plastics treaty is needed to ambitiously reduce plastic production, phase out harmful subsidies, eliminate products and chemicals of concern, and adopt strong national plans and rigorous reporting and compliance mechanisms.

Environmental impacts

Plastic pollution poses a threat to the marine environment. It puts marine species at higher risk of ingesting plastic, suffocating, or becoming entangled in plastic pollution. Research indicates that more than 1,500 species in marine and terrestrial environments are known to ingest plastics. The Organization for Economic Cooperation and Development (OECD) estimated that in 2019, plastic products were responsible for 3.4% of global greenhouse gas emissions throughout their life cycles, with 90% of these emissions coming from the production and conversion of fossil fuels into new plastic products. OECD also reports that, unless human behavior changes, greenhouse gas emissions associated with the life cycle of plastic products are expected to double by 2060. The World Economic Forum projects that without intervention, the global plastics industry will account for 20% of total oil consumption and up to 15% of global carbon emissions by 2050.

Plastic waste is one of the most serious environmental issues of our time. It has been estimated that over 300 million tonnes of plastic is produced annually and around 14 million tonnes of plastic end up in the oceans around the world. Not to mention the tonnes of plastic that end up in landfill or into the general environment each year. This can lead to the contamination of both land and water with plastic debris. To make matters worse, plastic does not degrade easily and can stay in the environment for a long time. Depending on the plastic it can take between twenty and five hundred years for the plastic to decompose. The plastic waste problem has been around for many years, but it is only recently that people have started recognizing it as a major environmental issue that needs to be addressed.

One of the main causes of plastic pollution is by the use of single use plastics. Common single use plastics include water bottles, straws, food containers, plastic bags and plastic packaging. As the name suggests this type of plastic is designed to be used once and then disposed of. This has the potential to cause a number of issues. While single-use plastics have made our lives convenient, this has come at a cost.

One of the big problem relates to the improper disposal of plastic. Much of the plastic waste comes from the single-use plastic types which are not always recycled. As a result, these plastics accumulate in the environment and ultimately cause plastic pollution. According to our

Every year, 19 - 23 million tons of plastic waste leak into aquatic ecosystems, causing serious pollution

world in data, 55% of these plastics will end up in landfills and 25% while are destined for incineration.

It is estimated that incinerating plastic in a single year will dump 850 million tonnes of greenhouse gases into the atmosphere. Greenhouse gas emissions also occur when the plastic industry manufacture new plastics since they use fossil fuels in their construction. This means that when plastic is disposed of through incineration the harmful effects are duplicated at the start and end of its life cycle. When this life cycle consists of just a single use it means the plastic material has a high cost in terms of environmental impact and for climate change. However not all plastics are destined for incineration or recycling. Some do not even get that far and instead are dumped in the environment where over time they decompose.

Plastic waste accumulates in the oceans, lakes, and rivers, and can choke and suffocate aquatic life. As mentioned, plastic also contains various toxins, which can leach into the environment and contaminate water sources. This can cause serious health problems for animals and humans. While fishing gear is a big source of plastic and general waste pollution in the ocean other forms of plastic such as single use plastics are also major contributors. 20% of ocean plastics is from sea-based sources, while 80% of the plastics found in the ocean are from land based sources.

Animals can ingest plastic and micro plastics have been found in the stomachs of marine life. The ingestion of plastics can cause the death of the animal, disrupting the lifecycle, food chains and the ecosystem that the animal is a part of. In addition to the plastic waste problem, there is also the problem of microplastics. Microplastics are tiny pieces of plastic, which are smaller than 5mm in size. These microplastics come from the breakdown of larger plastic materials, such as bottles and bags, and can accumulate in the environment. Recently, microplastic particles have even been found in human blood. The long term effects of this are still to be understood fully.

Once microplastics enter the environment they can be extremely difficult to deal with. Ultimately the best way to tackle issues surrounding microplastics is to address the tons of plastic that enter the environment in the first place through proper waste management, before they get a chance to break down into microplastics and cause environmental harm.

Human health impacts

According to the United Nations Environment Programme, microplastics have also been found in

human livers, kidneys, and placentas. Additionally, the International Union for Conservation of Nature finds that carcinogenic chemicals found in plastic products can leach into tap water, which may cause developmental, reproductive, neurological, and immune disorders. Some animal studies have raised similar concerns about endocrine-disrupting effects.

Microplastics have been found in human blood and placentas and in food and drinks, including tap water, beer, and salt. Several chemicals used in the production of plastic materials are known to be carcinogenic and can cause developmental, reproductive, neurological, and immune disorders. Discarded improperly, plastic waste pollutes and harms the environment, becoming a widespread driver of biodiversity loss and ecosystem degradation. It threatens human health, affects food and water safety, burdens economic activities, and contributes to climate change.

Marine wildlife impacts

Marine wildlife suffers the most direct and damaging effects of ocean plastic pollution. From all kinds of fish to turtles, seals, crustaceans, micro-organisms and many other forms of life, the damage caused by plastic pollution to marine animals is increasingly visible as we learn more about this problem. One of plastic's biggest assets as a material is its durability. However, this means that once plastic enters the ocean, it will persist there for long periods; it won't go away by itself.

Impacts on species and ecosystems

All land, freshwater, and marine ecosystems are affected by plastic pollution. Natural ecosystems provide a broad range of services that are not only fundamental for conservation, but also key for economies and human well-being. For example, healthy mangroves provide coastal protection services, whereas wetlands are important for freshwater provision. The most visible impacts of plastic debris are the ingestion, suffocation, and entanglement of species. Wildlife such as birds, whales, fish, and turtles mistake indigestible plastic waste for food and die of starvation as their stomachs become filled with it. It also causes internal and external injuries that reduce the ability to swim and fly. Domesticated farm animals are also affected by plastic pollution. Floating plastics transport invasive alien species, one of the leading causes of biodiversity loss and species extinction. Plastic pollution can also seep carcinogenic chemicals (such as those contained in certain plastic products or fireproofing coatings) into the soil. These can run into groundwater or rivers, affecting exposed people and ecosystems.

Any marine ecosystem is finely balanced, and any change to that balance can seriously impact the inhabitants. Floating plastic debris can allow species such as coastal organisms to spread far from their usual environments and thrive in the open ocean upsetting the balance in the GPGP. This can be damaging to marine life naturally occurring in ocean garbage patches, such as neuston. Some plastic not only contains harmful additives and chemicals but also acts as magnets for toxins from the surrounding air or water, so the longer a piece of plastic is out there, the more harmful it can become to any animal that ingests it.

Economic impacts

The build-up of plastic litter can have a negative impact on aspects of a country's economy and trade systems, with income declines in sectors such as small- and medium-enterprises, the informal sector, tourism, fisheries, agriculture, and water safety. IUCN's research on these economic impacts demonstrates examples and possible solutions.

Impacts on climate

Climate impacts begin with oil and gas extraction, the refining of these products into plastics, and then plastic pollution itself. Incinerated plastic waste releases greenhouse gases and other pollutants into the atmosphere, including carbon dioxide, dioxins, and methane. Plastic is a synthetic, organic polymer made from fossil fuels, such as gas and petroleum. Over 460 million metric tons of plastic are produced every year, according to the United Nations Environment Programme. Plastic is used in almost all consumer and industrial activities, from construction and vehicles to electronics and agriculture.

SOLUTIONS TO THE PLASTIC WASTE PROBLEM

The plastic waste problem is a global issue and requires global action. There are various ways the issues surround plastic waste can be tackled. Generally, they can be divided into four main categories: developing sustainable alternatives; reducing plastic usage; recycling plastic waste; implementing laws and regulations. One way of dealing with the plastic waste problem is to focus on sustainability and develop eco-friendly alternatives to plastic. This can be done in various ways and many companies have made strides in this area. Plastic has frequently been used as a material of convenience and in some cases alternative materials could not perform as well as its plastic counterparts or were simply cheaper to produce and therefore increased profit margins. However, with modern materials and processes this is not strictly the case any more.

Microplastics in the environment and food can cause many negative impacts on human health and the living environment

Moving away from plastic made with carbon polymers is something that has been tackled by a number of material manufacturers. There has been a lot of progress with the development of biodegradable materials, that can be used as plastic alternatives such as paper, bamboo, and corn starch. These materials are generally more eco-friendly, but historically have come at an increased cost. For some businesses the switch to different materials is less problematic but is still something that needs to be factored into production and sales costs. Legislation and taxes aside, finding alternative materials to use instead of continuing to focus on the production of plastic helps with one of the key elements of successfully tackling the plastic problem which is reducing plastic usage in the first place.

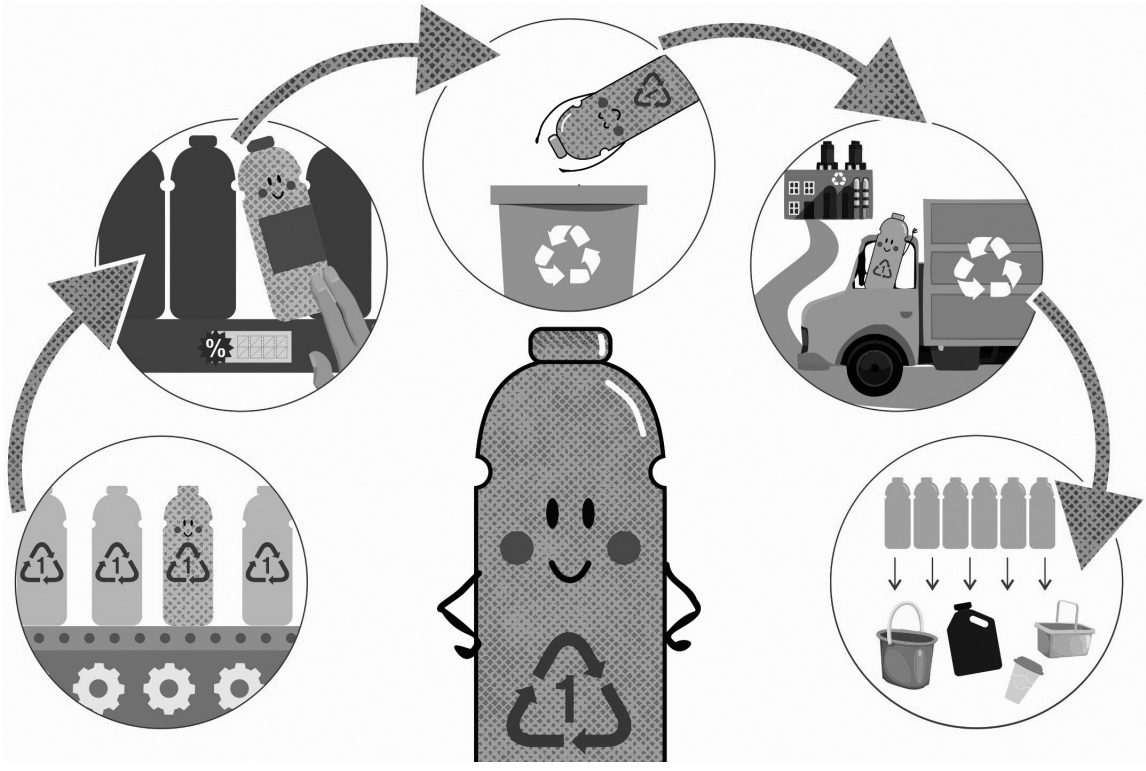
Reducing plastic usage

When it comes to materials and packaging in general, for some product types the material used in its production may not be as sustainable as you might imagine. One example is single use drink containers. The manufacturer of aluminium cans, glass bottles and plastic bottles all have a cost on the environment. Switching from plastic to one of the other materials may have some environmental benefits (plastic being a potential pollutant) but the real gains are found in terms of the products recyclability and the ability to recycle the material in the first place. Since in many locations all rubbish will end up being disposed of together and is not recycled at all, any material will likely have some negative environmental impact, especially if its primary purpose is single use only. This is why there have been incentives such as attempting to remove single use packaging at the point of sale. Reuse schemes can have a lot of positives but there also needs to be a consumer mind-shift away from convenience to pro-active engagement in plastic avoidance. Ultimately, the goal is an overall waste generation reduction which will tackle all forms of excessive manufacturing and not just virgin plastic.

This can be done by using reusable products, such as reusable bags and bottles, and by avoiding single-use plastics, such as straws and disposable plates. Ultimately, the goal being the reduction of single-use items which will reduce the need to manufacturer the item in the first place. Since single-use items are often made of plastic by moving to reusable containers it will help reduce the tons of plastic waste that enter the supply chain. These changes to the way a business operates can also save the business money once there has been a change in the mentality of the consumer away from convenience to conscientiousness.

Improved recycling

Improved recycling is another way to reduce plastic pollution. By recycling plastic waste, it can often be reused and repurposed into new products, which reduces the amount of plastic waste in the



When consumers switch to recycled products, it will reduce tons of plastic waste in the environment and help businesses save costs

environment. Recycling plastic comes with its own issues. While pretty much all plastic can technically be recycled, it is often not always practical or cost-effective to do so for every plastic type. Depending on where a person lives can have a big impact on what particular plastic types can or cannot be recycled. Improving waste management systems where people need them most will help tackle the problem of plastics and other materials not being effectively recycled. Improving the circular economy of the lifecycle of global plastics is paramount to helping the environment.

Implementing laws and regulations

As we have already touched on, governments have needed to address the plastic problem through increased legislation and dictates on what materials can be used for certain product types, typically revolving around single-use items. These laws and regulations have been introduced to help reduce the amount of plastic waste that is being created. This includes banning single-use plastics, such as straws and bags, and implementing taxes and fines on plastic products.

Many countries have already started to do this but there is no global mandate for this. Any initiative that currently implemented is on a country by country basis and therefore the effectiveness of these legislations tend to be limited. When legislations and laws can be an effective way to reduce plastic pollution, these rules need to be in place in the first place, and not every country is committed to the same degree.

A circular economy for plastics offers a sustainable path forward. This means we need to rethink how we design, make, use and reuse plastics. Products must be designed to be used more than once, and to be recycled at the end of their life. This shift must include all stakeholders across the plastics value chain. A just transition is crucial to protect the livelihoods of waste pickers and impacted communities, ensuring social equity and leaving no one behind. The removal of legacy plastics and prevention of pollution requires that fewer plastic products be made, that the circularity of supply and value chains be increased, and that consumer behaviour be changed. It also involves public and private investment and the development of infrastructure along the full lifecycle of plastics, including circular economy solutions like reuse, refill, etc■

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NGUYỄN THỊ THU THẢO

RULES FOR WRITING AND PUBLISHING ARTICLES IN THE JOURNAL OF ENVIRONMENT

The Journal of Environment, under the Institute of Strategy and Policy on Agriculture and Environment, Ministry of Agriculture and Environment, has the main function of introducing and publishing scientific information; scientific research works on strategies and policies in areas of agriculture and environment. Currently, the Journal is recognized by the State Council for Professorship for grades of scientific works for 05 Interdisciplinary Councils (Chemistry - Food Technology; Construction - Architecture; Biology; Irrigation; Agriculture - Forestry), facilitating considering and recognizing standards of Professor, Associate Professor, and post-graduate student with converted score of 0.25 - 0.5 grades of scientific works.

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Articles sent to the Journal of Environment for publication must not have been previously published in any scientific journal. Authors are responsible for not sending draft articles to other journals without a rejection decision from the Journal's Editorial Board. Authors are responsible for the content, accuracy of citations, legality and copyright of draft articles.

Articles sent for publication must be written in Vietnamese if sent for publication in the Vietnamese version of the Journal and in English if sent for publication in the English version of the Journal. Articles must be drafted using Microsoft Word software, with Times New Roman font size 13, line spacing 1.5; top margin 2.5 cm; bottom margin 2.5 cm; left margin 3 cm; right margin 2 cm; article length not exceeding 6,000 words for scientific research articles in Vietnamese and English versions; not exceeding 3,000 words for articles in categories Forum - Policy; Around the World; Policy - Practice.

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II. CONTENT OF AN ARTICLE PUBLISHED IN THE JOURNAL OF ENVIRONMENT

- Abstract: The author writes a brief paragraph (from 100 to 150 words), reflecting the main content of the article and fully presenting following aspects: (i) Importance and purpose of the research; (ii) Methods used for the research; (iii) Main results of the research. For a Vietnamese article, the author provides the title and abstract (including keywords) translated into English (it is requested not to use automatic translation tools) and presented right below the Vietnamese abstract.

- Keywords: The author needs to provide 3 to 5 keywords of the article in alphabetical order representing characteristics of the topic of the article.

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- Theoretical framework and Methods: (i) Clearly present the overview of the research and related theoretical basis; (ii) Theoretical framework or analytical framework used in the article (if any); (iii) Methods used for the research; (iv) Description of the location of the research (if any).

- Results and discussion: (i) Interpret and analyse new findings; (ii) Draw general relationships and connections between results of the author's research and other findings in previous researches.

For some articles of a policy advisory or critical nature, expert opinions need to focus on assessing the current status of issues of the research (assessing achievements, limitations and causes...).

- Conclusion or/and policy implications: Depending on objectives of the research, a summary conclusion must ensure following contents: (i) Results of the research; (ii) Limitations of the research; (iii) Opening up new research directions; (iv) Providing solutions or recommendations for business managers and/or policy makers based on results of the research.

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- References: The presentation of reference citations is important in assessing the depth and seriousness of the research. Therefore, reference citations must be presented according to standards. Reference citations are divided into two main types: In-text references and list of references. The list of references is placed at the end of the article, each in-text reference must correspond to sources in the list of references.

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The Institute of Strategy and Policy on Agriculture and Environment was established under Decision No. 305/QD-BNNMT dated 1 March 2025 of the Minister of Agriculture and Environment. Accordingly, the Institute has the position and function of a public science and technology unit for state management under the Ministry of Agriculture and Environment, assisting the Minister in studying, proposing and developing strategies and policies on areas under the Ministry's state management; conducting scientific researches, providing public, consulting and training services in areas of agricultural and rural development, poverty reduction, natural resource management, environmental protection and climate change response in accordance with legislations.

The Institute of Strategy and Policy on Agriculture and Environment has legal status, its own seal and account; is headquartered in Hanoi City; and operates under the mechanism of a public science and technology organization.

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